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(3)

Supreme Court, U.S.
FILED

081209 MAR 27 2009

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In The Supreme Court of the United States

PELLA CORPORATION AND W.L. GORE & ASSOCIATES, INC.,

Petitioners,

v.

ANDERSEN CORPORATION,

Respondent.

On Petition For A Writ Of Certiorari To The United States Court Of Appeals For The Federal Circuit

APPENDIX TO PETITION FOR A WRIT OF CERTIORARI VOLUME II

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APPENDIX VOLUME II

TABLE OF CONTENTS

Page

U.S. Patent No. 6,880,612 ..... App. II-1

Technical Information [High Transparency Wire Mesh], from http://www.twpinc.com/high_trans.html (July 28, 2002) ..... App. II-35

(12) **United States Patent**
Pylkki et al.

(10) **Patent No.: US 6,880,612 B2**
(45) **Date of Patent: Apr. 19, 2005**

(54) **REDUCED VISIBILITY INSECT SCREEN**

(75) Inventors: **Russell John Pylkki**, St. Paul, MN (US); **Patrick Jerome Grouland**, Star Prairie Twonship, WI (US); **Rodney Kieth Williams**, Stacy, MN (US); **Kurt E. Heikkila**, Marine on the St. Croix, MN (US)

(73) Assignee: **Andersen Corporation**, Bayport, MN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/259,221**

(22) Filed: **Sep. 26, 2002**

(65) **Prior Publication Data**

US 2003/0150569 A1 Aug. 14, 2003

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/068,069, filed on Feb. 6, 2002.

(51) **Int. Cl.**[7] **E06B 9/52**
(52) **U.S. Cl.** **160/371**; 245/8
(58) **Field of Search** ..... 174/35 MS; 160/371; 139/420 A; 442/181, 189

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,333,518	A	* 11/1943	Simms	442/49
2,364,404	A	* 12/1944	Thomas	139/420 R
2,381,542	A	8/1945	Hyatt et al.	
2,665,754	A	1/1954	Claussen et al.	
3,255,810	A	6/1966	Rowbottam	
3,276,942	A	10/1966	Ewing	
3,321,003	A	5/1967	Boerner	
3,480,069	A	11/1969	Handwerker	
3,552,476	A	1/1971	LeTarte	
4,002,188	A	1/1977	Hanks	

(Continued)

FOREIGN PATENT DOCUMENTS

DE	200 20 267	U1	5/2001
FR	2272629	A1	12/1975
GB	2086254	*	5/1982

(Continued)

OTHER PUBLICATIONS

"Aluminum Insect Screen Cloth", http://www.wire-cloth.com/aluminum-screens.htm, 2 pgs. (Last Revised Jul. 11, 2002).

"Aluminum Insect Screening", http://www.phifer.com/alumsc.htm, 1 pg. (Printed Jul. 14, 2002).

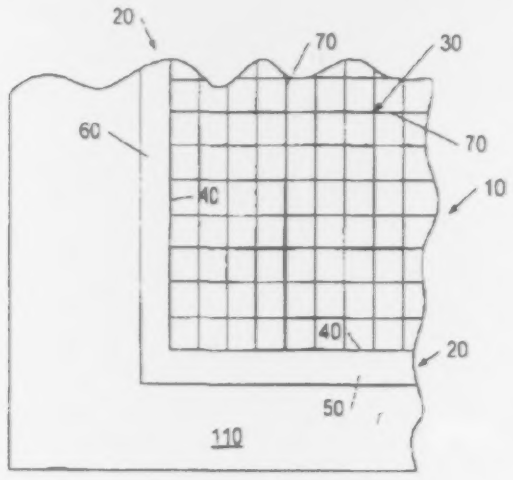
"Basic Wire Cloth and Wire Mesh Weaving Methods", http://www.wire-cloth.com/weaves.htm, 1 pg. (Last Revised Jul. 11, 2002).

Primary Examiner—Blair M. Johnson
(74) *Attorney, Agent, or Firm*—Womble Carlyle Sandridge & Rice, PLLC

(57) **ABSTRACT**

A reduced visibility insect screening is described having a transmittance of at least about 0.75 and a reflectance of about 0.04 or less. In an alternative embodiment, an insect screening material includes screen elements having a diameter of about 0.005 inch, having a bond strength greater than 5500 psi, and having the same transmittance and reflectance limits. In another embodiment of the invention, a screening includes screen elements having a diameter of about 0.005 inch or less and a coating on the screen elements having a matte black finish, where the screening has the same transmittance and reflectance limits.

77 Claims, 21 Drawing Sheets



U.S. PATENT DOCUMENTS

4,137,353	A	1/1979	Fanello	
4,241,123	A	12/1980	Shih	
4,247,737	A	1/1981	Johnson et al.	174/35 MS
4,253,737	A	3/1981	Thomsen et al.	359/614
4,412,255	A	10/1983	Kuhlman et al.	
4,468,702	A	8/1984	Jandrell	348/819
4,562,675	A	1/1986	Baiges, Jr. et al.	
4,587,997	A	5/1986	Brooks	
4,661,376	A	4/1987	Liang	427/126.1
4,772,092	A	9/1988	Hofer et al.	
4,819,085	A	4/1989	Liang	348/819
4,869,389	A	9/1989	Cerrone, Jr.	
4,980,227	A	12/1990	Sekiguchi et al.	
5,012,041	A	4/1991	Sims et al.	
5,037,455	A	8/1991	Scheinesoo et al.	
5,066,085	A	11/1991	Gimbutas et al.	
5,139,076	A	8/1992	Langdon	
5,198,287	A	3/1993	Samson et al.	
5,312,467	A	5/1994	Wolfe	
5,392,835	A	2/1995	Wildt	
5,453,252	A	9/1995	Truett	
5,492,551	A	2/1996	Wolfe	
5,679,232	A	10/1997	Fedor et al.	
5,728,632	A	3/1998	Sugie	
5,775,400	A	7/1998	Wilkinson	
5,785,792	A	7/1998	Locke et al.	
5,828,494	A	10/1998	Strempple	
5,951,727	A	9/1999	Spies et al.	
6,096,371	A	8/2000	Haaland et al.	
6,109,331	A	8/2000	Story, Jr.	
6,125,905	A	10/2000	Woodside et al.	
6,164,361	A	12/2000	Meyer	
6,183,872	B1	2/2001	Tanaka et al.	
6,186,215	B1	2/2001	DeYoung et al.	
6,235,388	B1	5/2001	Yamamoto et al.	
6,331,223	B1	12/2001	Wylie et al.	
6,341,444	B1	1/2002	Cina et al	
6,429,750	B1	8/2002	Curran et al.	333/12
6,479,143	B1	11/2002	Tamaru et al.	
6,497,946	B1	12/2002	Kretman et al.	
2001/0042348	A1	11/2001	Landahl	
2002/0134709	A1 *	9/2002	Riddle	209/238
2002/0137410	A1	9/2002	Porter et al.	
2003/0173042	A1	9/2003	Haas	

FOREIGN PATENT DOCUMENTS

GB	2161194 A	1/1986
GB	2 178 765 A	2/1987
JP	60-28547	2/1985
JP	9-195646	7/1997
JP	2000-27568	1/2000
NL	9500121	11/1995

OTHER PUBLICATIONS

"Bronze Insect Screens", http://www.wire-cloth.com/bronze-screens.htm, 1 pg. (Last Revised Jul. 11, 2002).

"Comparative Gauge/Decimal Wire Diameters", http://www.wire-cloth.com/reference/gauge.htm, 3 pgs. (Last Revised Jan. 3, 2002).

"Detailed Product Specifications for Woven Wire Cloth and Wire Mesh are Illustraied in the Various Product Group Tables", http://www.wire-cloth.com/products.htm, 2 pgs. (Last Revised Jul. 11, 2002).

"Fiberglass Insect Screening", http://www.phifer.com/fiber.htm, 1 pg. (Printed Jul. 28, 2002).

"Fibreglass Insect Screening", http://www.rjreid.co.nz/screen.html, 1 pg. (Printed Jul. 28, 2002).

"Fine Mesh Wire Cloth", http://www.wire-cloth.com/fine-mesh.htm, 2 pgs. (Last Revised Jul. 11, 2002).

"Galvanized Steel Insect Mesh", http://www.wire-cloth.com/galvanized-screens.htm, 1 pg. (Last Revised Jul. 11, 2002).

"Insect Screening Mesh", http://www.lockerwire.co.uk/Insect.htm, 1 pg. (Printed Jul. 28, 2002).

"Light Transmitting Fabric", http://www.rjreid.co.nz/lfab.html, 1 pg. (Printed Jul. 28, 2002).

"Market Grade Wire Cloth", http://www.wire-cloth.com/market-cloth.htm, 2 pgs. (Last Revised Jul. 11, 2002).

"Mill Grade Wire Cloth", http://www.wire-cloth.com/mill-cloth.htm, 2 pgs. (Last Revised Jul. 11, 2002).

"Specialty Screen Products", http://www.hanoverwire.com/hscreen.htm, 2 pgs. (Printed Jul. 14, 2002).

"Stainless Steel Insect Screens", http://www.wire-cloth.com/stainless-screens.htm, 1 pg. (Last Revised Jul. 11, 2002).

"Tensile Bolting Cloth", http://www.wire-cloth.com/bolting-cloth.htm, 2 pgs. (Last Revised Jul. 11, 2002).

"Technical Information [High Transparency Wire Mesh]", http://www.twpinc.com/high_trans.html, 2 gs. (Printed Jul. 28, 2002).

"Technical Information [Insect Screen]", http://www.twpinc.com/insect.html 2 pgs. (Printed Jul. 28, 2002).

"Technical Information [Welded Stainless Mesh]," *TWP Inc.*, 2831 Tenth Street, Berkeley, CA 94710, http://www.twpinc.com/welded.html,2 pgs. (Printed Feb. 4, 2003).

"Toyota Wire Cloth," *Toyota Tsusho America, Inc.*, http://www.ttaiwirecloth.com/screenprinting, 2 pgs. (Last modified Jul. 16, 2002).

"Toyota Wire Cloth—Top Quality Screen Printing Cloth," *Toyota Tsusho America, Inc.*, http://www.ttaiwirecloth.com/screenprint-cloth, 3 pgs. (Last modified Jul. 2, 2002).

Screen Technology Group, Inc., Bolting Cloth, Apr. 26, 1998.

The Ludlow-Saylor Wire Company, Manufacturers of The Perfect Double Crimped Wire Cloth and Rex-Tang Screen for Mining and All Other Purposes, Jul. 14, 1938, p. 14, 15 and 61, Catalogue No. 46, Saint Louis, Mo., U.S.A.

The Ludlow-Saylor Wire Company, Manufacturers of The Perfect Double Crimped Wire Cloth and Rex-Tang Screen for All Purposes, Aug. 1, 1924, p. 116-117, Catalogue No. 47, Saint Louis, Mo., U.S.A.

Buffalo Wire Works Company Incorporated (Formerly Scheller's Sons), Jan. 8, 1916, p. 47, 49, and 62: Catalog No. 8, Buffalo, N.Y., U.S.A.

The 1958 Wire Industry Encyclopaedic Handbook, A Comprehensive Reference Book for the Wire-Drawing and Wire Fabricating Industries, May 2, 1958, p. 1, 2, 418-421, 438, and 439, The Wire Industry Limited, London, England.

"Insect Screens," http://www.gothicarchgreenhouses.com/insect_screens.htm, 2 pgs., printed Oct. 22, 2004.

"Celebrating the Past, Focusing on the Future," Window & Door, Feb. 2003.

"Insect Screening," The National Greenhouse Manufacturers Association, 1996 11 pgs.

"Open Weaves," http://www.sefaramerica.com/isa/weaves/weaves2.htm, 2 pgs., printed Oct. 22, 2004.

"Vision Screens Components and Sizes," http://www.phantomscreens.com/products/viscomponentsframe.html, 2 pages. printed Oct. 22, 2004.

Laramore, L., "Introduction to Photographic Principles," May 1965, 202–205, Dover Publications, New York, NY USA.

Woodson, W. E., et al., "Human Factors Design Handbook" 1992, 322–343, 352–412, 654–674, 2nd Ed., Mc–Graw Hill, Inc., USA.

Hecht, E., "Optics," 2002, 215–217, pp. 254–255, 258–269, 393–396, 441, 443–485, 490–501, 507–509, 550–554, 560–573, 606–619 4th ed., Addison Wesley, San Francisco, CA, USA.

Majumder, A., "ICS 280: Visual Perception." http://www.ics.uci.edu/~majumder/docs/spatialvision.pdf, Feb. 4, 2004, 13 pages, University of California at Irvine, Irvine, CA, USA.

Nafziger, J., "Structure of the Retina," Vision Lecture 2004, University of Arizona, http://www.optics.arizona.edu/Nofziger/OPTI%20200/Lecture%2029/200VisionLecture%201%20JMP.pdf, pp. 1–30.

Clark, R. N., "Optimum Magnified Visual Angle Visual Astronomy of the Deep Sky," http://www.clarkvision.com/visastro/omval, last modified Mar. 24, 2002, 12 pages.

Green, M., "Determining Visibility," Visual Expert Human Factors, http://www.visualexpert.com, printed Nov. 23, 2004, 4 pages.

Kalloniatis, M., et al., "Visual Acuity," Webvision The Organization of the Retina and Visual System. John Morgan Eye Center, The University of Utah, http://webvision.med.utah.edu/index.html, Last updated Aug. 2003, Part IX, 15 pages.

Green, M., "'Inattentional Blindness' & Conspicuity," Visual Expert Human Factors, http://www.visualexpert.com, printed Nov. 23, 2004, 6 pages.

Blackwell, H. R., "Contrast Thresholds of the Human Eye," Journal of the Optical Society of America, Nov. 1946, 624–643, vol. 36, No. 11.

Ferwerda, J. A., "Fundamentals of Spatial Vision," 1998, 1–15, Program of Computer Graphics, Cornell University, New York, USA.

Robison, G. T., "Powder Coating Ups Quality of Window Screen," Products Finishing, Sep. 1976, 42–47, Gardner Publications, Inc., Cincinnati, Ohio, USA.

Coren, S., et al., "Sensation and Perception," 2004, pp. 1–12, 43–77, 84–115, 216–231, 472, 6th Ed., John Wiley & Sons, Inc., Hoboken, New Jersey, USA.

"Insect Screening," 1996, 2 pages. The National Greenhouse Manufacturers Association, Littleton, Colorado, USA.

"Insect Screening." 2002, 2 pages, The National Greenhouse Manufacturers Association, Littleton, Colorado, USA.

"Recommended Standards and Specifications for Insect Wire Screening (Wire Fabric), "Insect Screening Weavers Association, May 4, 1990.

* cited by examiner

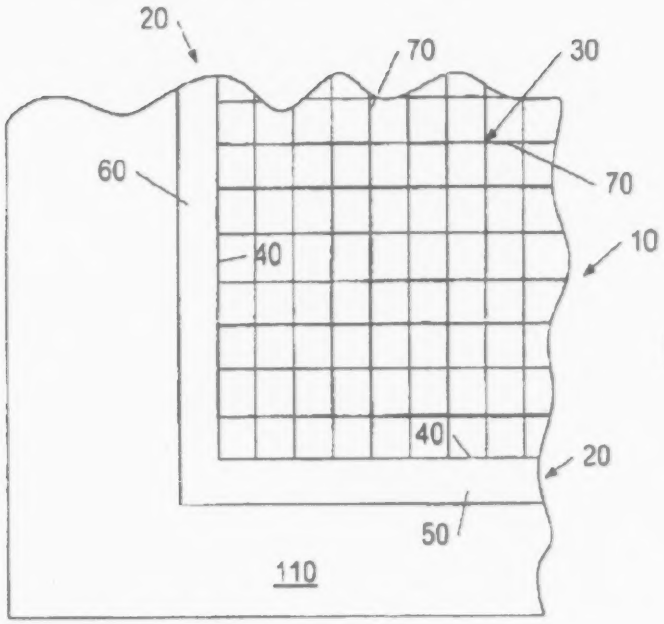


FIG. 1

FIG. 2

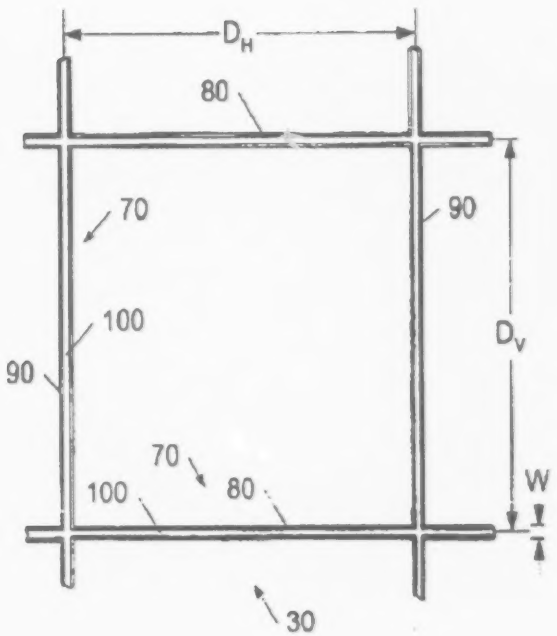
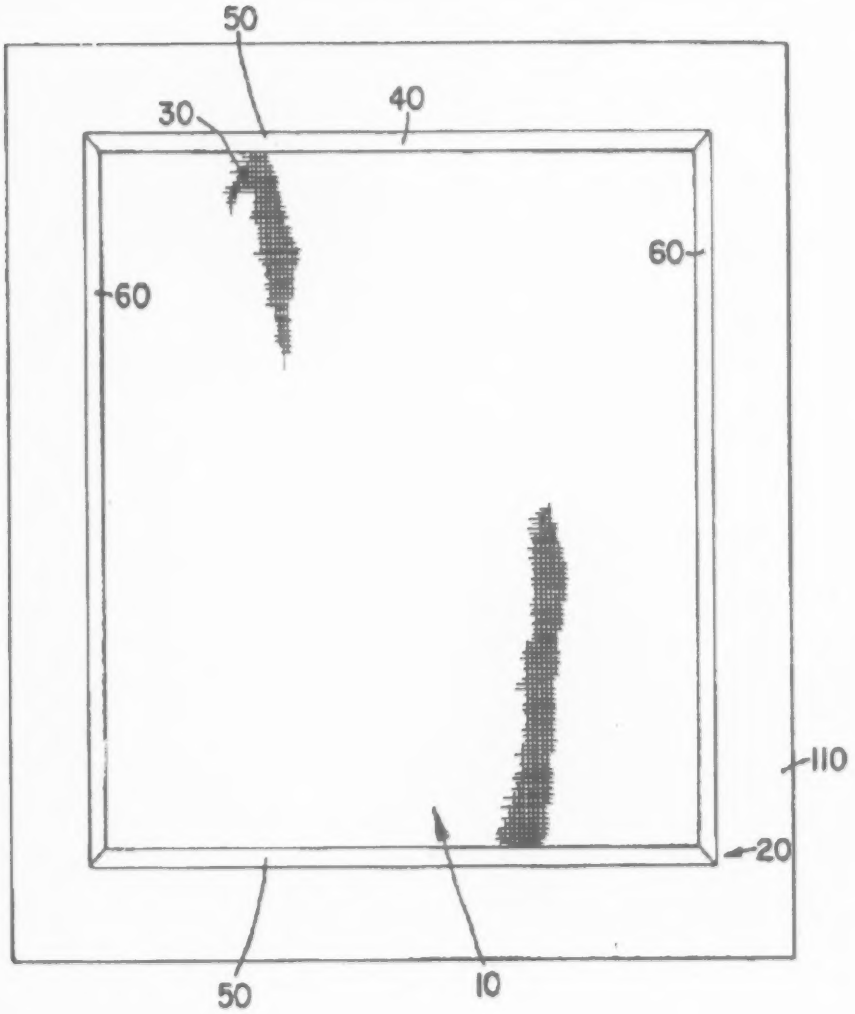


FIG. 3



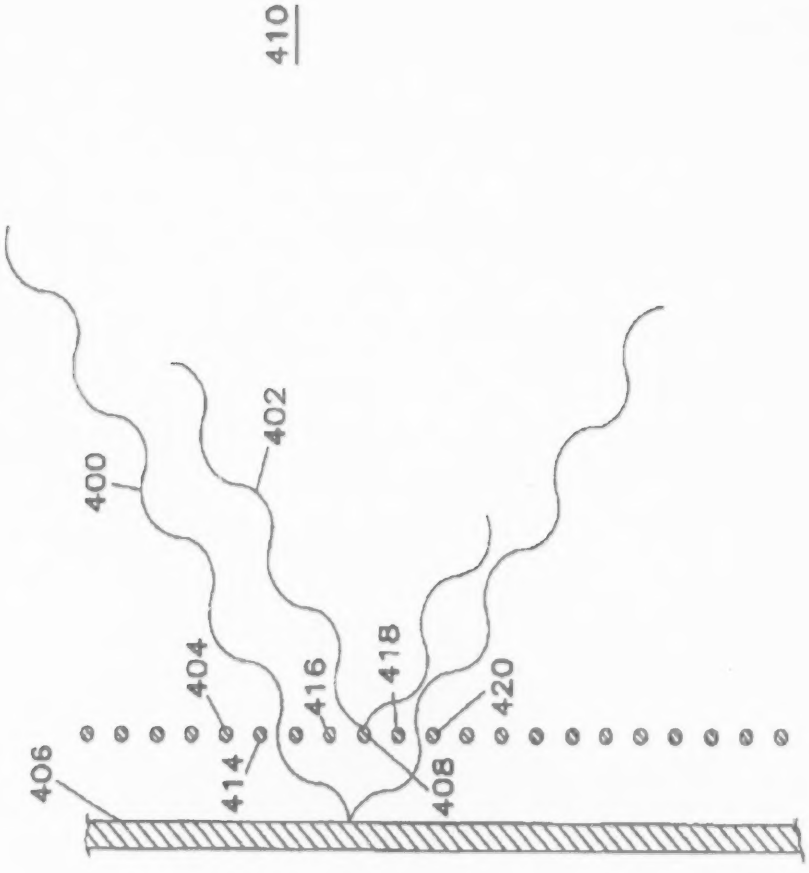


FIG. 4

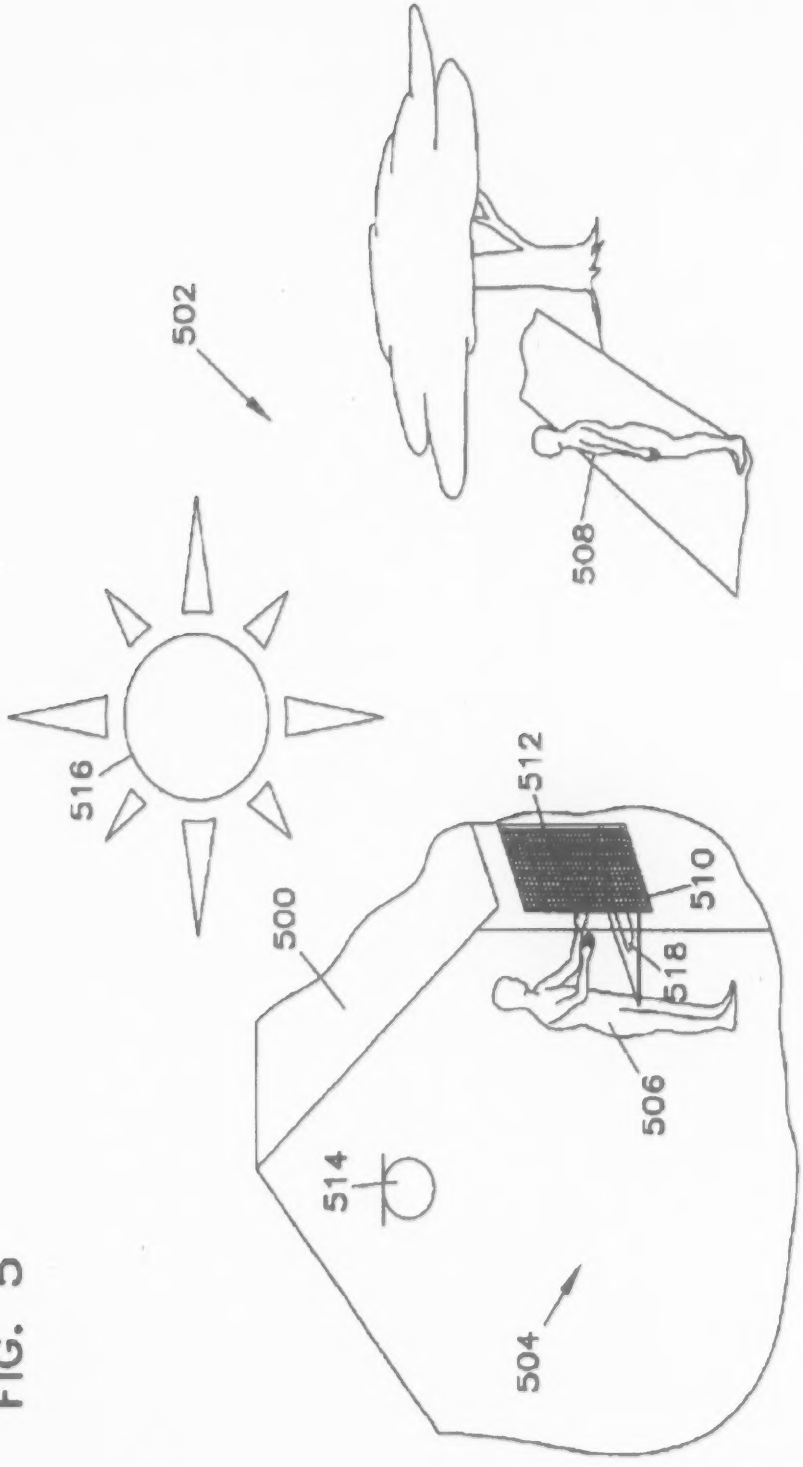


FIG. 5

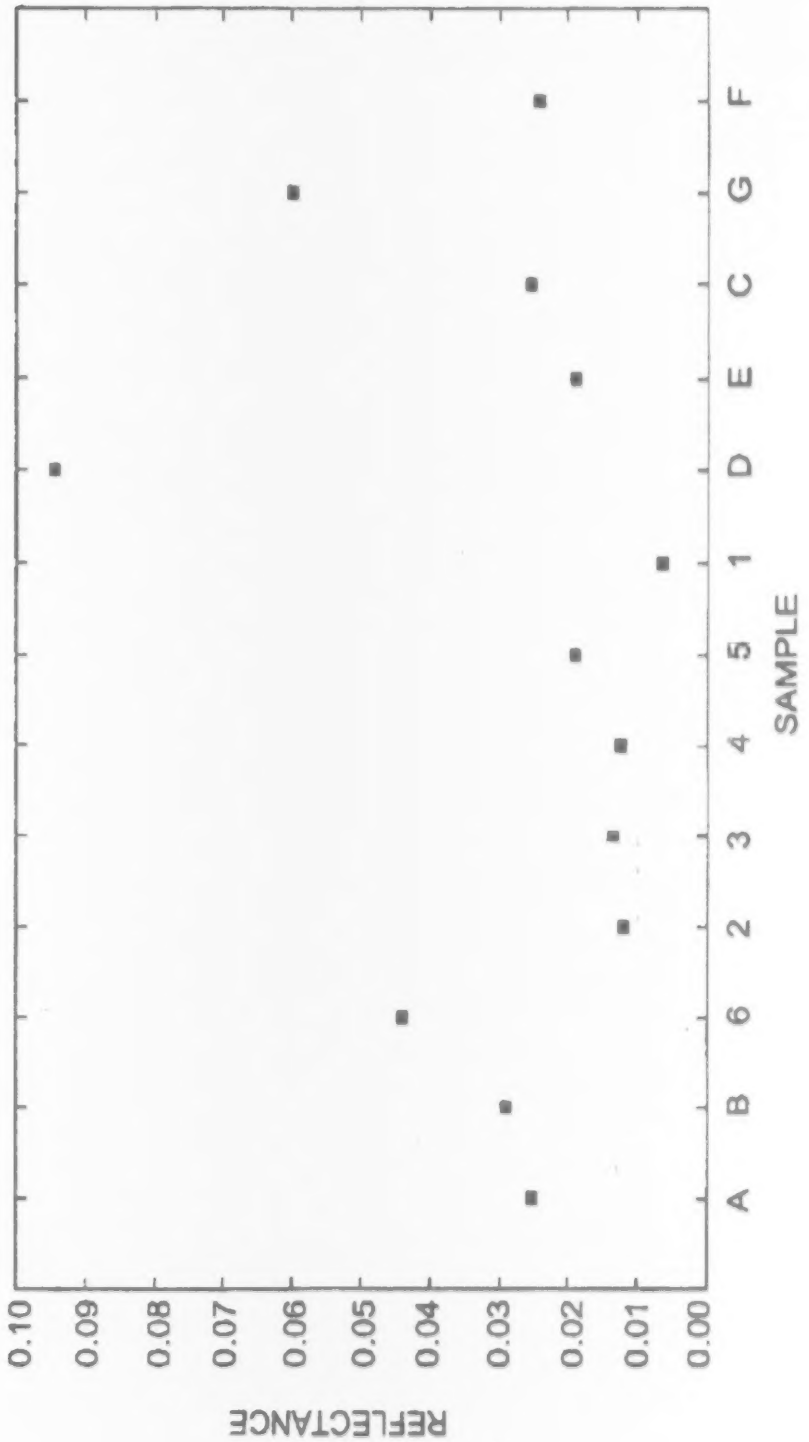

REFLECTANCE
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
SAMPLE
A
B
6
2
3
4
5
1
D
E
C
G
F

FIG. 6

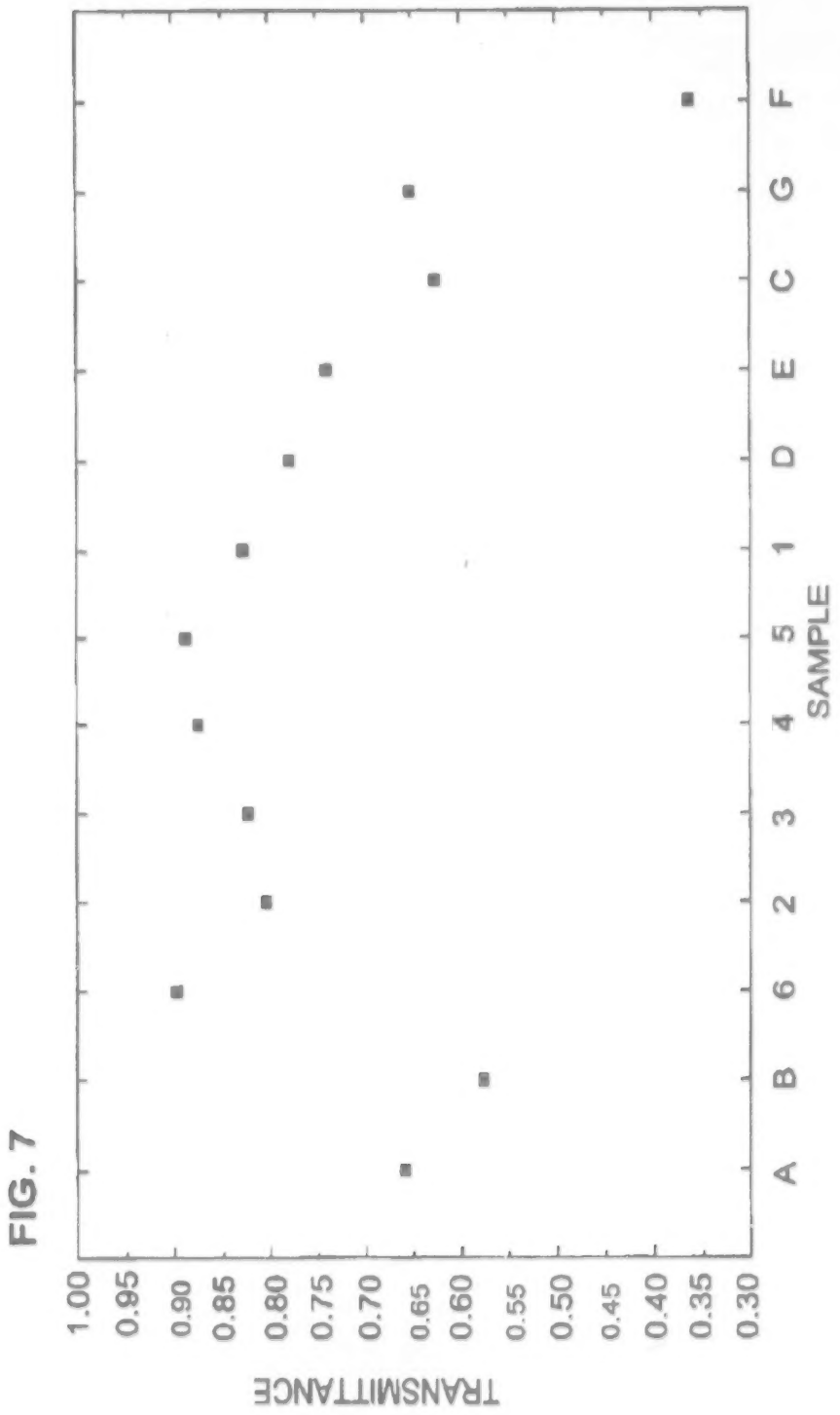

TRANSMITTANCE
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
SAMPLE
A
B
6
2
3
4
5
1
D
E
C
G
F

FIG. 7

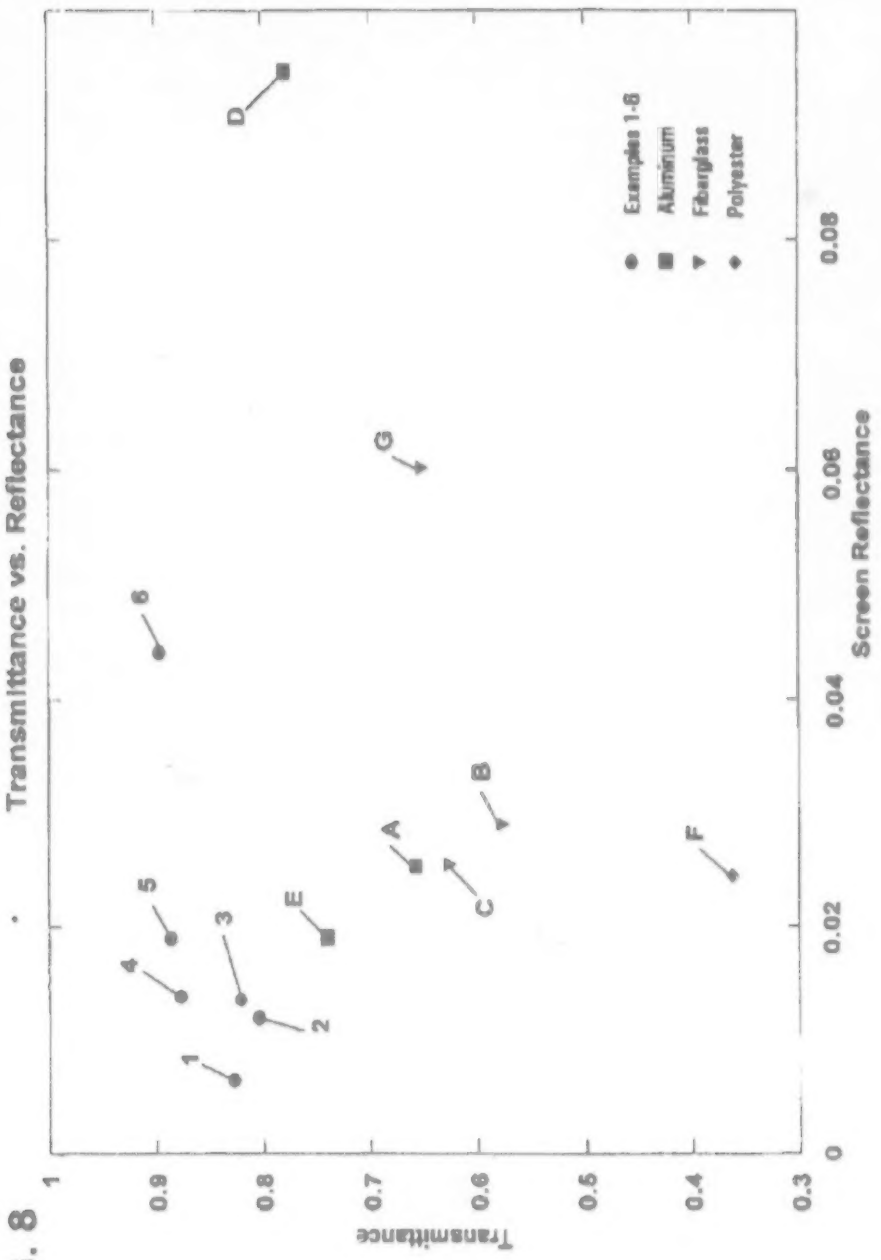

Transmittance vs. Reflectance
Transmittance
Screen Reflectance
Examples 1-6
Aluminum
Fiberglass
Polyester
1
2
3
4
5
6
A
B
C
D
E
F
G
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.02
0.04
0.06
0.08

FIG. 8

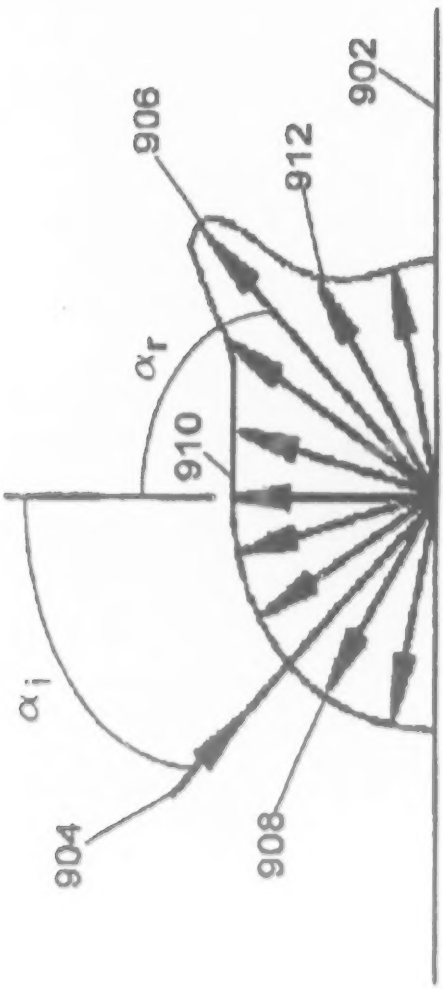


FIG. 9

FIG. 10

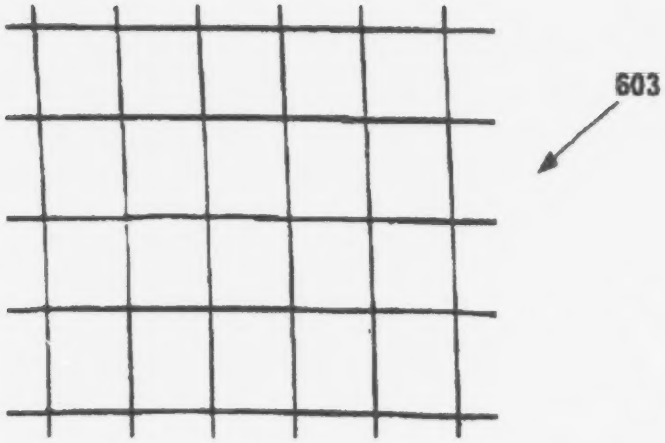


FIG. 14

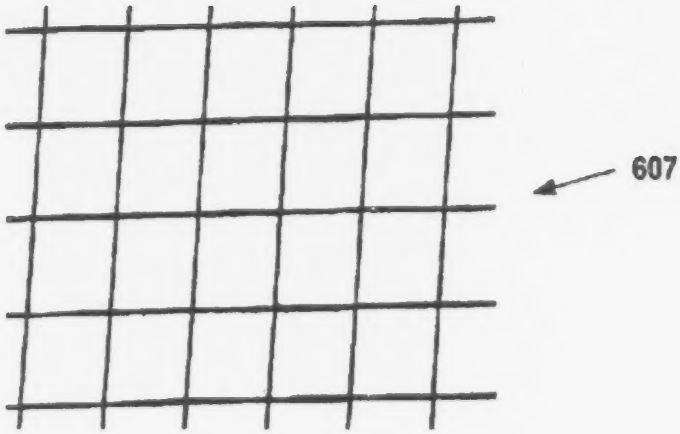


FIG. 11

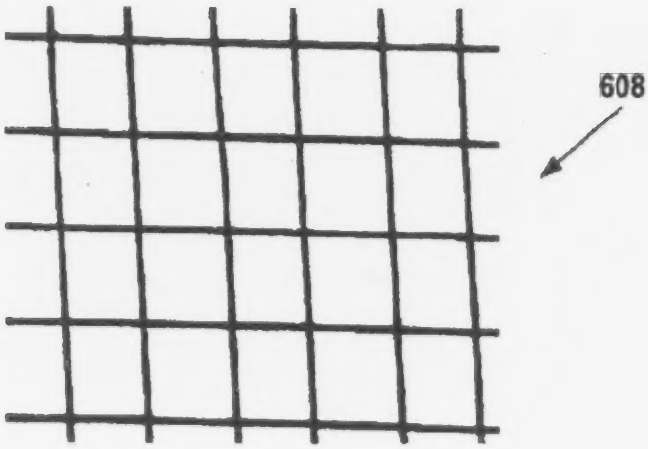


FIG. 12

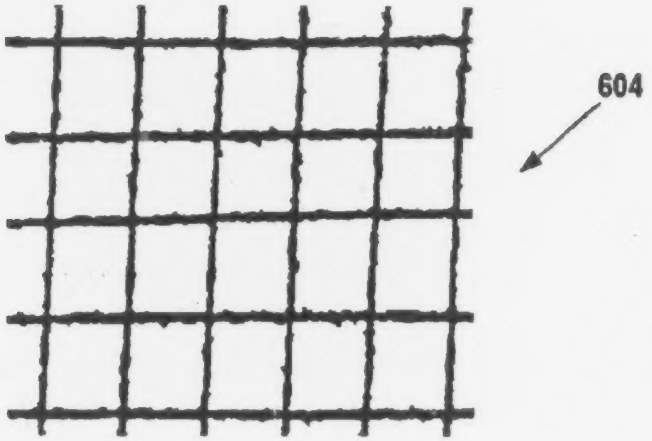
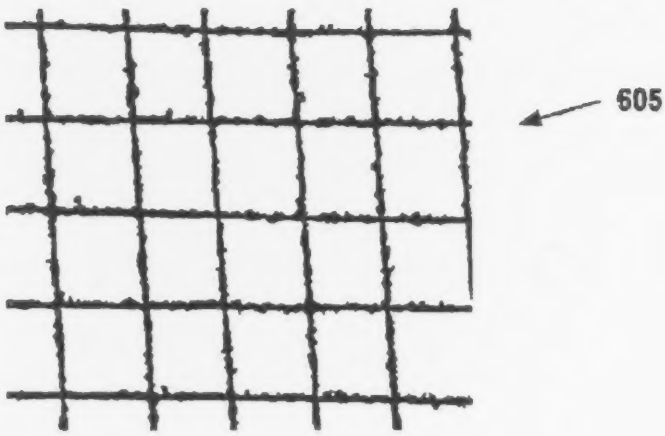


FIG. 13



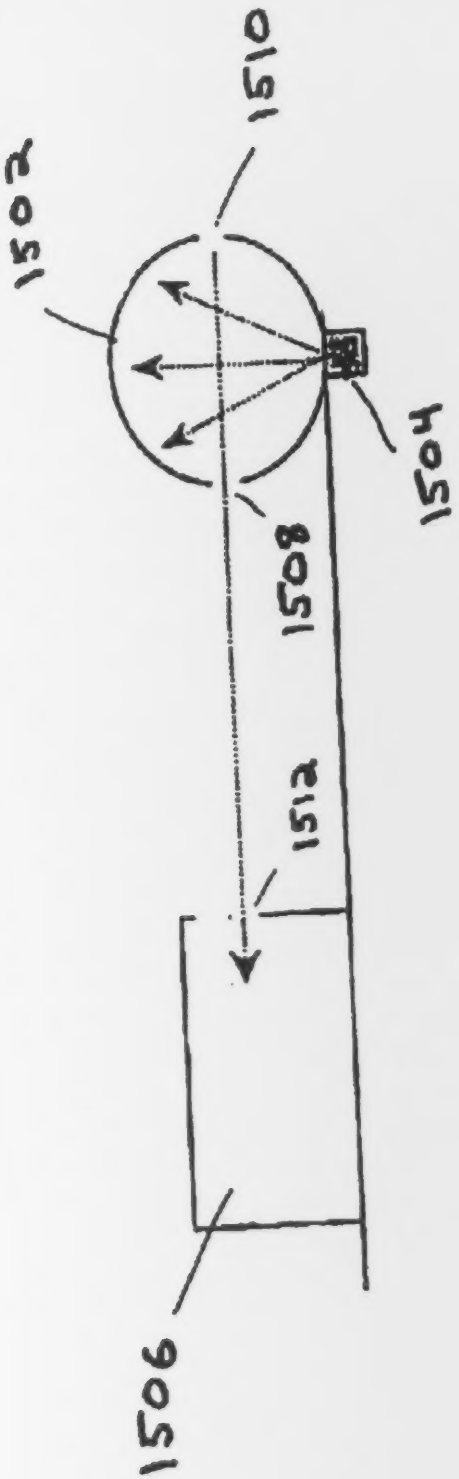


FIG. 15

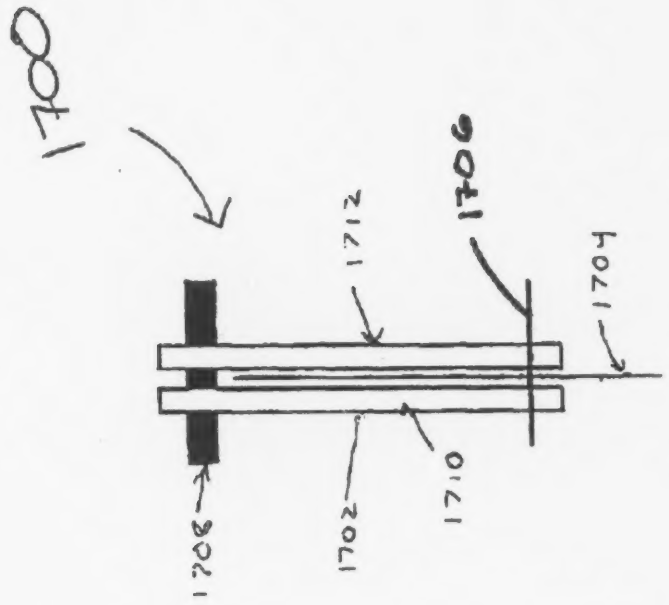


FIG 17

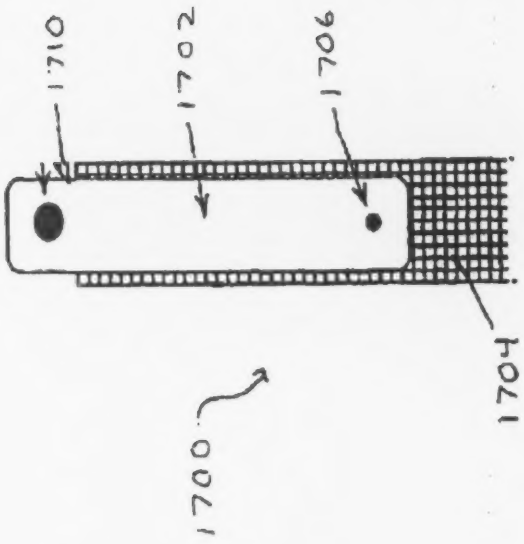


FIG 16

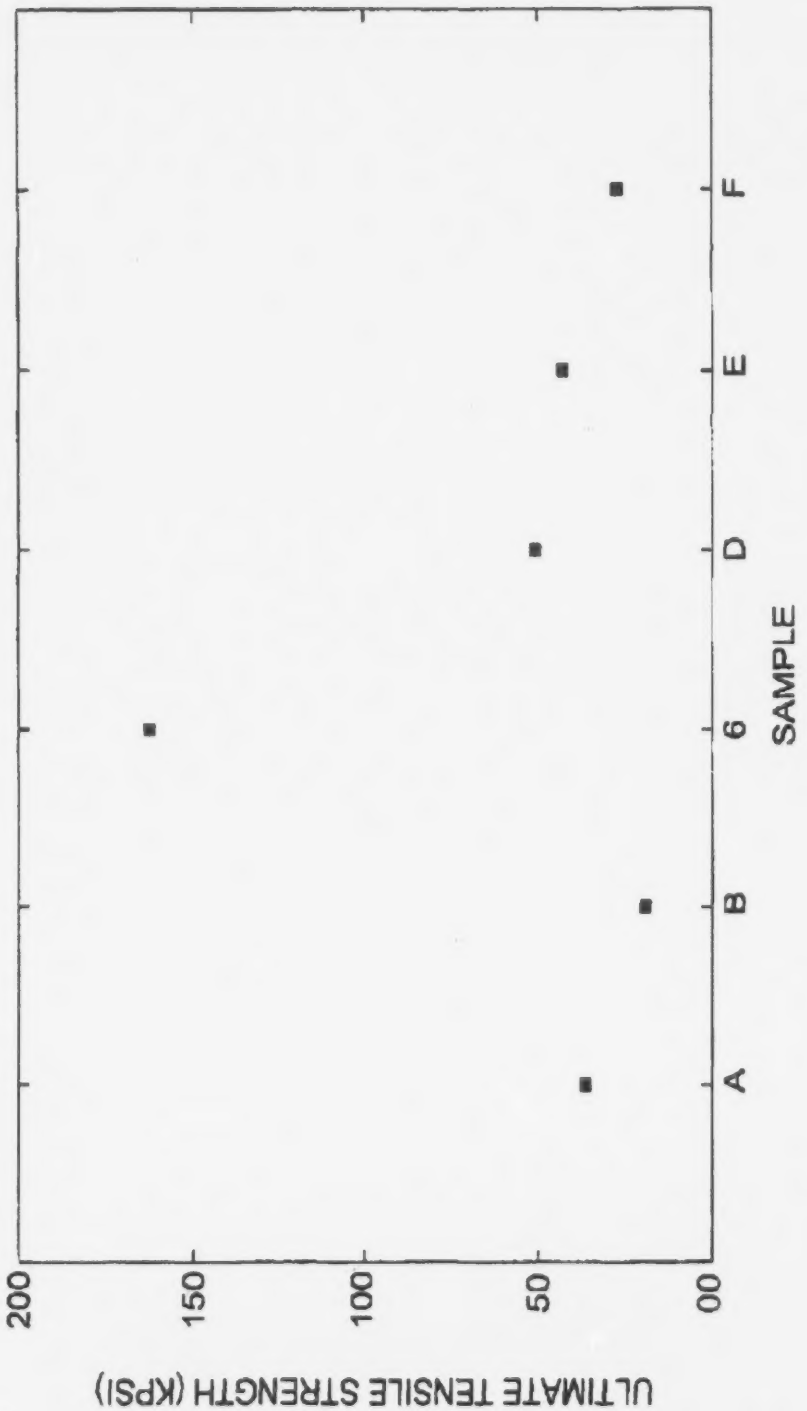

ULTIMATE TENSILE STRENGTH (KPSI)
200
150
100
50
00
A
B
6
D
E
F
SAMPLE

FIG. 18

FIG. 19

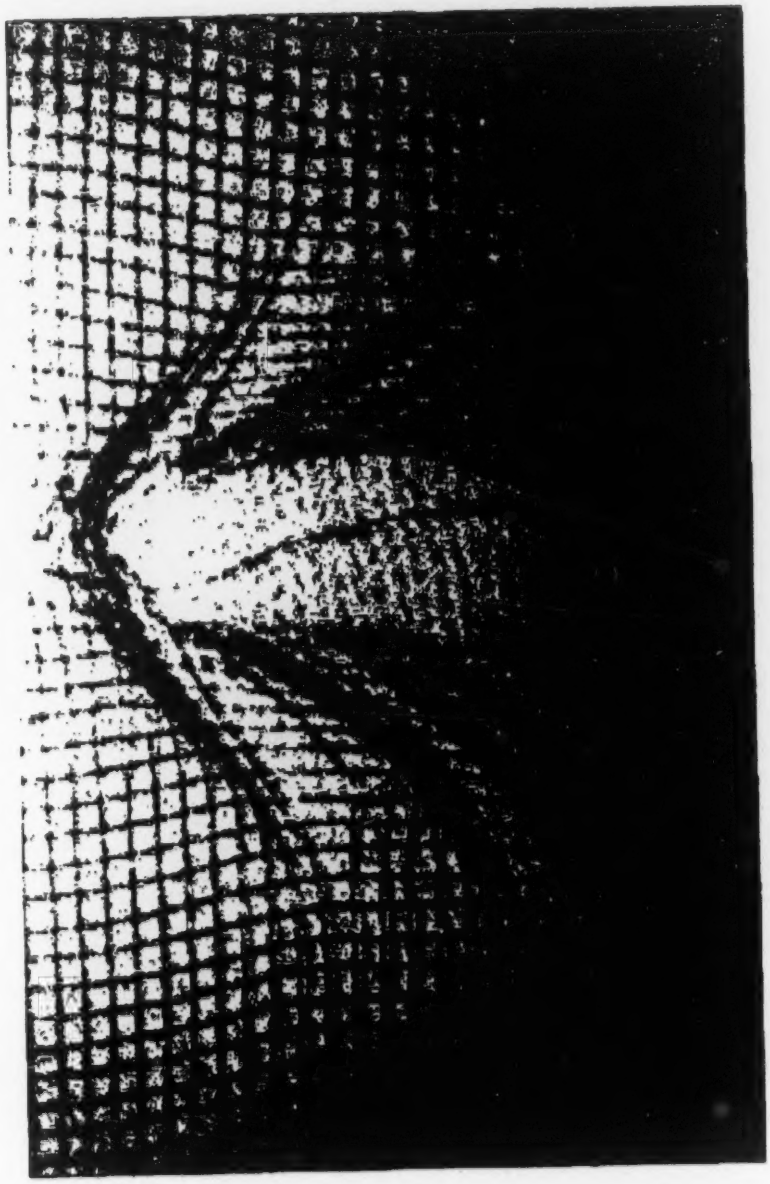


FIG. 20

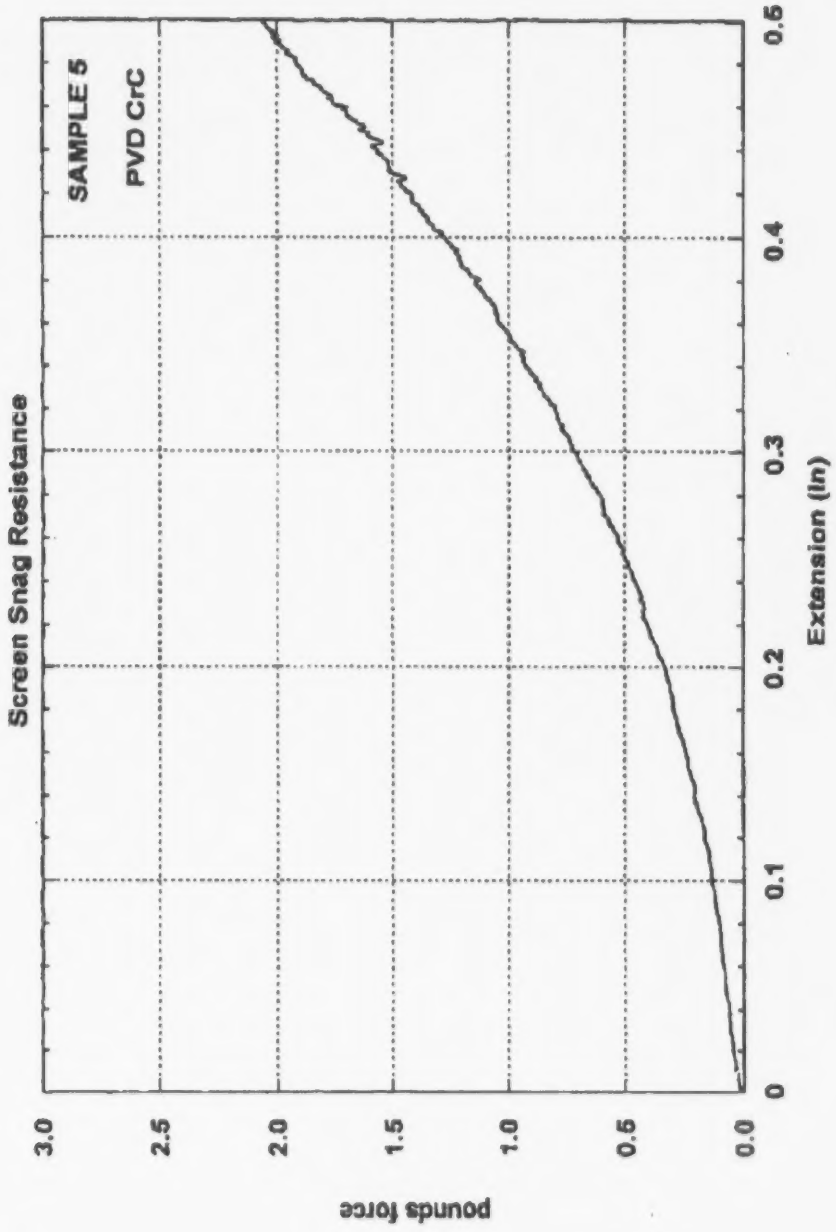

SAMPLE 5
PVD CrC
Screen Snag Resistance
pounds force
Extension (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
0.1
0.2
0.3
0.4
0.5

FIG. 21

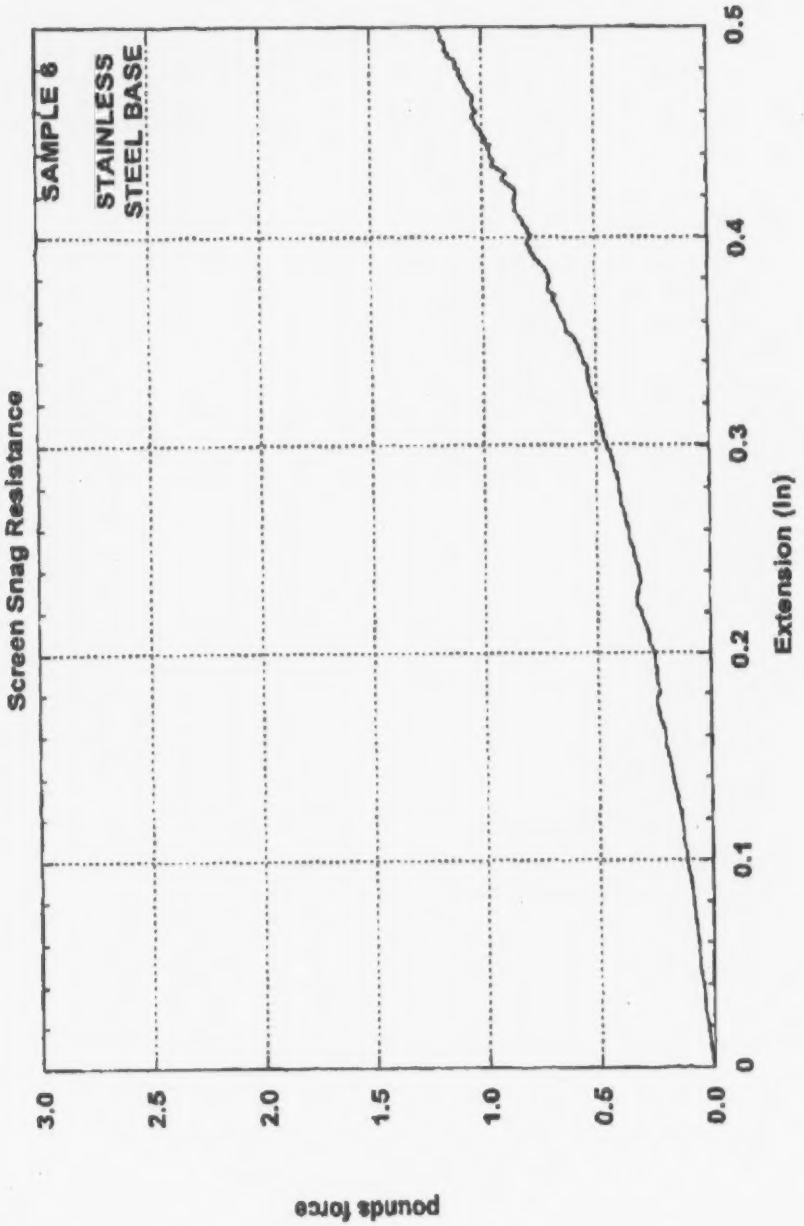

Screen Snag Resistance
SAMPLE 6
STAINLESS STEEL BASE
pounds force
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Extension (In)
0
0.1
0.2
0.3
0.4
0.5

FIG. 22

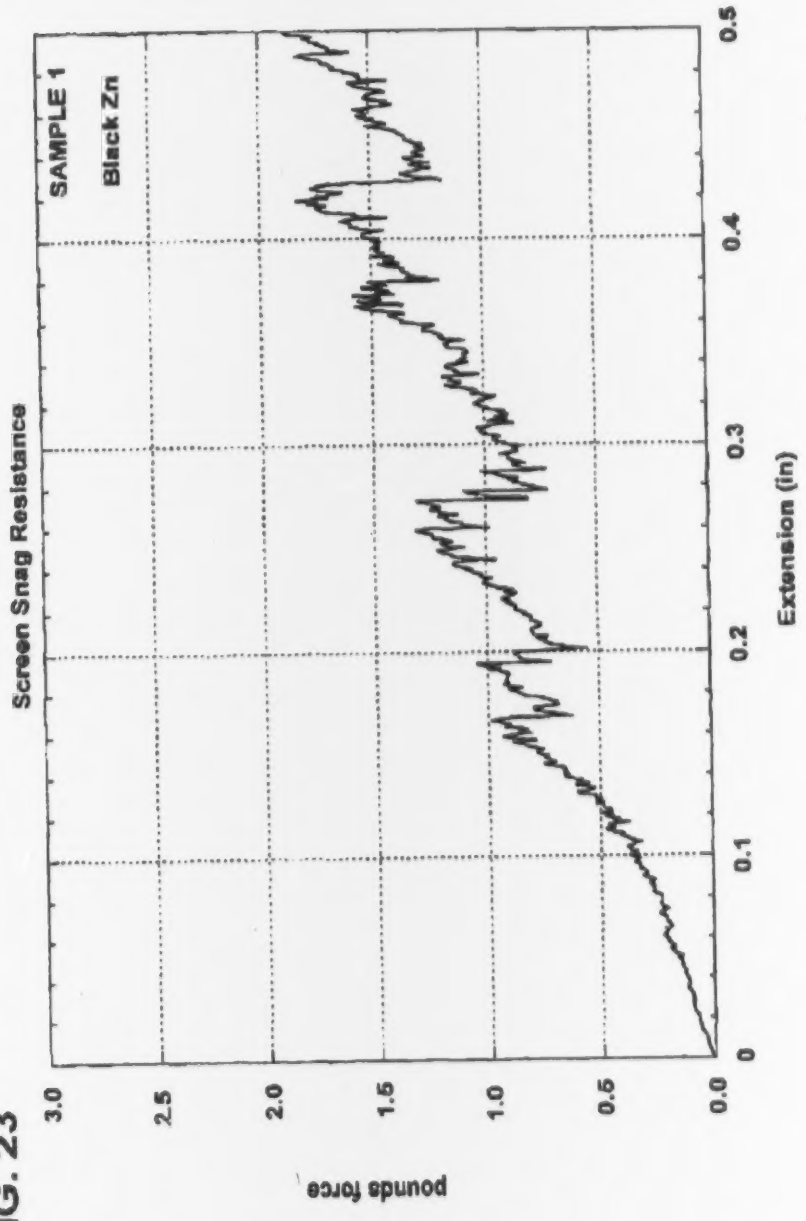

Screen Snag Resistance
SAMPLE 1
Black Zn
pounds force
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
0.1
0.2
0.3
0.4
0.5
Extension (in)

FIG. 23

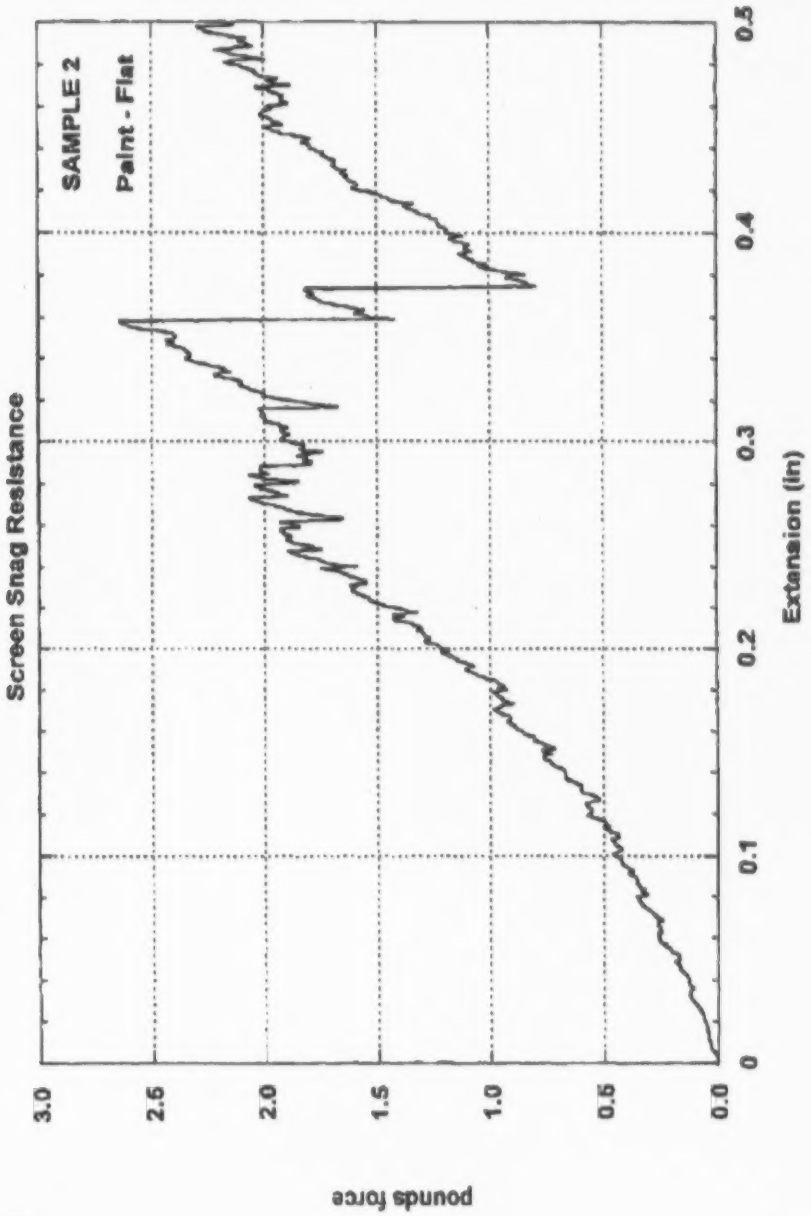

SAMPLE 2
Paint - Flat
Screen Snag Resistance
Extension (in)
pounds force
0
0.1
0.2
0.3
0.4
0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

FIG. 24

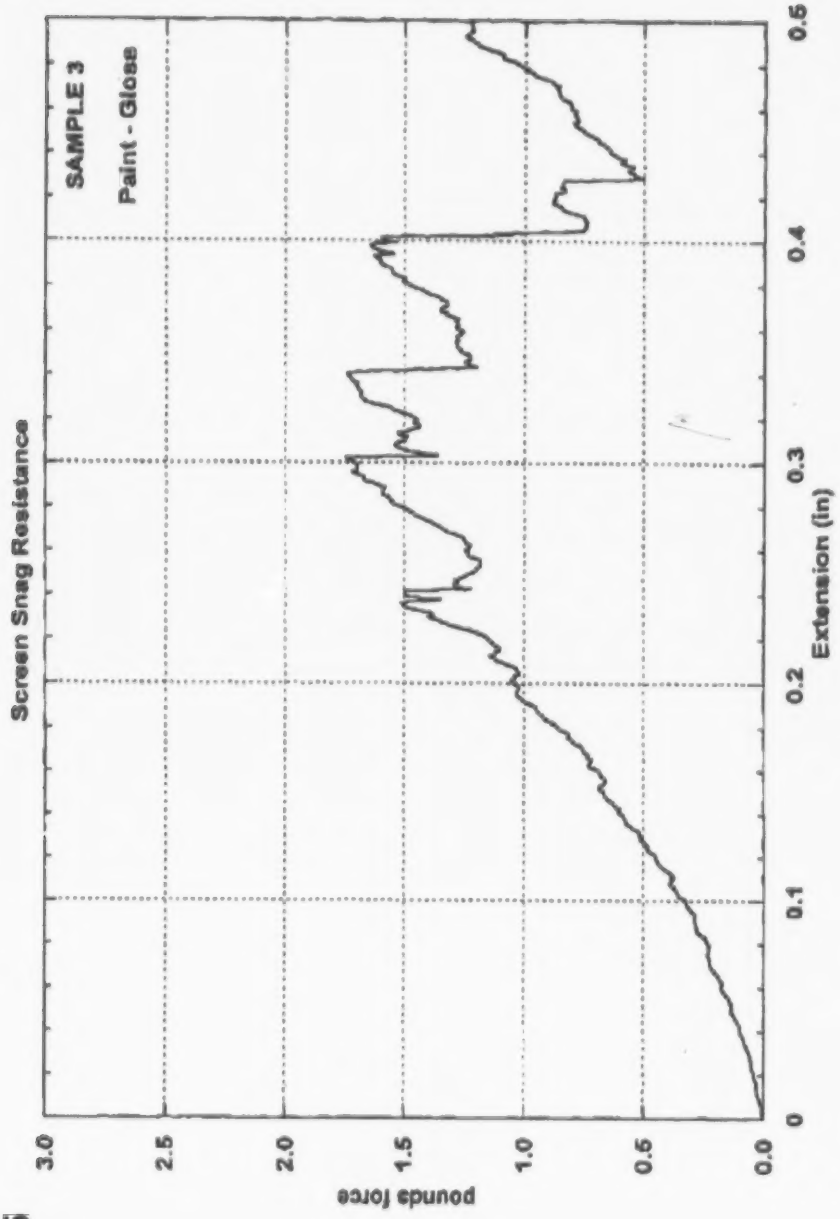

SAMPLE 3
Paint - Gloss
Screen Snag Resistance
pounds force
Extension (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
0.1
0.2
0.3
0.4
0.5

FIG. 25

REDUCED VISIBILITY INSECT SCREEN

CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation in part of co-pending U.S. application Ser. No. 10/068,069, filed Feb. 6, 2002, titled "REDUCED VISIBILITY INSECT SCREEN," which is hereby incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The invention relates to insect screens such as, for example, for windows and doors, that are less visible than conventional insect screens. A screen or screening is a mesh of thin linear elements that permit ventilation but excludes insect pests. To the ordinary observer, the screens are less visible in the sense that the interference to observing a scene either on the exterior or the interior of the screen is substantially reduced.

BACKGROUND OF THE INVENTION

Insect screens are installed on windows and doors in homes to promote ventilation while excluding insects. Insect screens are, however, widely regarded as unattractive. From the inside of a window, some screens obstruct or at least distract from the view to the outside. From the outside, many people believe that screens detract from the overall appearance of a home or building. Homebuilders and realtors frequently remove screens from windows when selling homes because of the improved appearance of the home from the outside. Homeowners frequently remove screens from windows that are not frequently opened to improve the view from the inside and the appearance of the window.

A wide variety of insect screen materials and geometries are available in the prior art. Fiberglass, metallic and synthetic polymer screens are known. These screens suffer from reduced visual appeal due to relatively low light transmission, high reflection or both. Standard residential insect screens include a mesh with horizontal and vertical elements. The most common insect screens have about 18 elements per inch in one direction and 16 elements per inch the other direction, often expressed as being a 18×16 mesh. Some standard screens have a 18×14 mesh. The typical opening size is about 0.040 inch by 0.050 inch. Screens designed to exclude gnats and other very small insects usually include screen elements in a 20×20 mesh. The most common materials for the screen elements are aluminum and vinyl-coated fiberglass. Stainless steel, bronze and copper are also used for insect screen elements. Typical element diameters for insect screens are 0.011 inch for aluminum, bronze and some stainless steel offerings and 0.009 inch for galvanized steel and stainless steel.

Some products on the market advertise a black or charcoal colored screen mesh that is allegedly less visible from the inside of a house. Color coating changes and material changes have made some incremental improvements in the visual appeal of screening to the average observer, but most observers continue to object to the darkening effect that current insect screening causes in observing screens from inside and outside.

SUMMARY OF THE INVENTION

We have found unique features for the elements used to form insect screening that maximize transmission and minimize reflection resulting in reduced visibility of the screening and enhanced viewing through it. The awareness of the insect screen is substantially reduced while the ability to observe details of the viewed scene is greatly enhanced.

A reduced visibility insect screening is described where the transmittance of the screening is at least about 0.75 and the reflectance of the screening is about 0.04 or less.

In an alternative embodiment, an insect screening material includes screen elements having a diameter of about 0.005 inch (about 0.127 mm) or less. The screen elements have a tensile strength of at least about 5500 psi (about 37.921 mega Pascals). Again, the transmittance of the screening is at least about 0.75 and the reflectance of the screening is about 0.04 or less.

In another embodiment of the invention, a screening is described including screen elements having a diameter of about 0.005 inch (about 0.127 mm) or less and a coating on the screen elements having a matte black finish. The transmittance of the screening is at least about 0.75 and the reflectance of the screening is about 0.04 or less.

In further alternative embodiments, the transmittance of the screening is at least about 0.80 or the reflectance of the screening is about 0.03 or less, or 0.02 or less. The screening material may have an open area of at least about 75%, or at least about 80%. The screening may define mesh openings having a largest dimension not greater than about 0.060 inch (about 1.524 mm).

The screen elements may have a diameter less than about 0.005 inch (about 0.127 mm), and may have a tensile strength greater than about 5500 psi (about 37.921 mega Pascals). The screen elements may be made of a metal such as steel, stainless steel, aluminum and aluminum alloy, or a polymer such as polyethylene, polyester and nylon. Alternatively, the screen elements may be made of an ultra high molecular weight polyethylene or an amide such as polyamide, polyaramid and aramid.

In one embodiment, the screen elements include a coating, specifically a black matte coating such as electroplated black zinc. In one embodiment the screen elements are made of stainless steel with an electroplated black zinc coating.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood by considering the detailed description of various embodiments of the invention that follows in connection with the accompanying drawings.

FIG. **1** is a fragmentary view of an insect screen in accordance with the invention.

FIG. **2** is a fragmentary view of a portion of the insect screen shown in FIG. **1**.

FIG. **3** is a perspective view of the insect screen shown in fragmentary view in FIG. **1**.

FIG. **4** is a diagram illustrating light paths in reflection from a window unit with a screen.

FIG. **5** is an illustration of inside and outside viewing perspectives of an insect screen on a window unit.

FIG. **6** is a graph showing the reflectance for embodiments of the invention and comparative example screen embodiments.

FIG. **7** is a graph showing the transmittance for embodiments of the invention and comparative example screen embodiments.

FIG. **8** is a graph showing the transmittance versus the reflectance for embodiments of the invention and comparative example screen embodiments.

FIG. **9** is a diagram showing specular and diffuse reflections from a matte surface.

FIG. **10** is a photograph taken through a microscope of uncoated screen elements.

FIG. **11** is a photograph taken through a microscope of stainless steel screen elements coated with a coating of electrodeposited black zinc.

FIG. 12 is a photograph taken through a microscope of stainless steel screen elements coated with flat paint.

FIG. 13 is a photograph taken through a microscope of stainless steel screen elements coated with gloss paint.

FIG. 14 is a photograph taken through a microscope of stainless steel screen elements coated with chromium carbide through a physical vapor deposition (PVD) process.

FIG. 15 is a diagram of an integrating sphere spectrophotometer for measuring the reflectance and transmittance of a screen material.

FIG. 16 is a front view of a test fixture for measuring the snag resistance of a screen material.

FIG. 17 is a side view of the test fixture of FIG. 16.

FIG. 18 is a graph showing the single element ultimate tensile strength for embodiments of the invention and comparative example screen embodiments.

FIG. 19 is a depiction of a snag on an unbonded insect screening.

FIG. 20 is a depiction of a snag on an insect screening having a paint coating.

FIGS. 21–25 are graphs plotting pounds of force applied to a rigid element versus inches of travel as the element moved against a screen mesh fabric for a snag resistance test for five different examples of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

We have found unique features for insect screening of the invention. We have found that by reducing the size of and selecting proper color and texture for the elements used in the screening, reflection and transmission are controlled such that the visibility of the screening is markedly reduced. The insect screening of the invention maintains comparable mechanical properties when compared to prior art insect screening, but is substantially improved in visual appearance. The insect screening of the invention can be used in the manufacture of original screens and can be used in replacement screens for windows, doors, patio doors, vehicles and many other structures where screening is used. The insect screening of the invention can be combined with metal frames, wooden frames or composite frames and can be joined to fenestration units with a variety of joinery techniques including adhesives, mechanical fasteners such as staples or tacks, splines, binding the screening material into recesses in the screen member frame or other common screen joining technology. When properly installed in conventional windows and doors, the ordinary observer viewing from the interior or the exterior through the insect screening of the invention has a substantially reduced awareness of the screening and a substantially improved ability to observe the scene on the other side of the screen.

We have found that the combination of reduced element size in the screening and coating on the screen elements combine to provide the improved visual properties of the insect screening of the invention. The selected materials disclosed for the screening of the invention are not limiting. Many different materials can satisfy the requirements of the invention.

Screen Within Frame and on Fenestration Unit

FIG. 1 is a fragmentary drawing of a portion of an insect screen **10** in accordance with the present invention. The insect screen **10** consists of a frame **20** including a frame perimeter **40** defining a frame opening. An insect screening **30** fills the opening defined by the frame perimeter **40**. The frame **20** supports the screening **30** on all sides of the screening **30**. The frame **20** is preferably sufficiently rigid to support the screening tautly and to allow handling when the screen **10** is placed in or removed from a window or door unit.

FIG. 2 is a fragmentary view of a portion of the insect screening shown in FIG. 1. The spaces between screen elements **70** define openings or holes in the screening **30**. In a preferred embodiment, the screen elements **70** include horizontal elements **80** and vertical elements **90**. Preferably, the horizontal and vertical elements **80**, **90** are constructed and arranged to form a mesh where a horizontal metal element intersects a vertical metal element perpendicularly. The intersecting horizontal and vertical metal elements **80**, **90** may be woven together. Alternatively, the intersecting horizontal and vertical metal elements **80**, **90** may be fused together although they may or may not be woven.

FIG. 3 is a perspective view of the insect screen shown in FIG. 1 positioned in a fenestration unit **110**. The frame **20** includes two pairs of opposed frame members. A first pair of opposed frame members **50** is oriented along a horizontal frame axis. A second pair of opposed frame members **60** is oriented along a vertical frame axis. The four frame members **50**, **60** form a square or rectangle shape. However, the frame may be any shape.

Goal of Making Screen Less Visible

When light interacts with a material, many things happen that are important to the visibility of insect screening. The visibility of screening can be influenced by light transmission, reflection, scattering and variable spectral response resulting from element dimensions, element coatings, and the dimensions of the mesh openings. In order to reduce the visibility of the screening, the transmittance is maximized, the reflectance is minimized, the remaining reflection is made as diffuse as possible, and any spectral reflectance is made as flat or colorless as possible. To accomplish this, it is beneficial to use screen elements with the smallest dimensions possible while still meeting strength requirements. Maximizing the dimensions of the grid openings will decrease visibility, but the dimensions of the grid openings are also chosen to achieve the desired insect exclusion and strength qualities.

In measuring to what degree an insect screening has achieved reduced visibility, the inventors have found that transmittance and reflectance are the most important factors for visibility of a screen from the exterior of a home. Because the sun is a much stronger light source than interior lighting, visibility of the screen from the exterior of the home is more difficult to reduce than visibility from the interior, as discussed further herein. Also, in double hung windows, the presence of an insect screen on the bottom half of the window contrasts with bare sash on the top half of the window to make the screening stand out.

FIG. 4 shows light paths for one typical viewing situation involving an observer outside a building looking at a screen and window. FIG. 4 shows a cross sectional view of screen **404** and glass **406** in the window. The window separates an exterior viewing location **410** from an interior scene **412**, where the screen **404** is on the exterior side of the glass **406**. Screen units are commonly positioned on the exterior of the glass, for example, in double-hung windows, sliding windows and sliding doors. Screening **404** is comprised of many elements, including elements **408**, **414**, **416**, **418**, and **420**. FIG. 4 generally illustrates the path of light ray **400** and light ray **402** as they interact with screen **404** and glass **406**. Light rays **402** and **404** are from the sun, which typically dominates the effects of any interior lights during a sunny day. The paths of light ray **400** and light ray **402** depict the ways in which reflectance and transmission affect the visibility of a screen for an outside observer of an exterior screen.

For example, light **402** travels toward glass **406** and reflects off element **408** in a direction away from glass **406**. Reflectance is the ratio of light that is reflected by an object compared to the total amount of light that is incident on the object. Solid, non-incandescent objects are generally viewed in reflection. (It is also possible to view an object in an

aperture mode where it is visible due to its contrast with a light source from behind it. A smaller screen element size decreases the visibility of a screen viewed in the aperture mode.) Accordingly, objects generally appear less visible if they reflect lower amounts of light. A perfectly reflecting surface would have a quantity of 1 for reflectance, while a perfectly absorbing surface would have a quantity of 0 for reflectance.

Another quantity that affects the visibility of screening is transmittance. When looking through screening, the viewer sees light emanating from or reflected from objects on the other side of the screening. As transmittance of the screening decreases, the viewer sees less light from the objects on the other side of the screening, and the presence of the screening becomes more apparent. Transmittance is defined as the ratio of light transmitted through a body relative to the total amount of light incident on the body. A value of 0 for transmittance would correspond to an object which light cannot penetrate. A value of 1 for transmittance would correspond to a perfectly transparent object. In the case of a window in a home viewed through an exterior insect screen by an outside observer, the light seen has traveled through the screen twice, as shown in FIG. **4**. For example, the light **400** travels away from the viewer and through the screen **404**. Next, the light is reflected off the window **406** and travels back through the screen **404** toward the outside viewer's eye.

Reducing the visibility of an exterior screen to an outside viewer is considered the most difficult because the intensity of sunlight is so much greater than lights within a building. If the visibility of an exterior screen for an exterior viewer is minimized, the screen will also be less visible for an inside viewer of an exterior screen, and for an inside and outside viewer of an interior screen. However, another important optical feature for invisibility of a screen to an inside viewer is a small element size, as will be further discussed. If the reflectance is minimized, the transmittance is maximized, and the screen element diameter is sufficiently small, the screening will be much less perceptible to inside viewers than conventional screens.

To achieve an insect screen that has reduced visibility, it is desirable to design insect screens with a low reflectance and high transmittance. Material choices and characteristics like color and texture can reduce reflectance. For example, dark matte colors reflect less light than light glossy colors or shiny surfaces. Reducing the cross-sectional area of the material and increasing the distance between the screen elements can increase transmittance. However, material that is too thin may not be strong enough to function properly in a typical dwelling. Similarly, insects may be able to pass through the screen if the distance between the elements is too large. Therefore, it is desirable to obtain a combination of strength, optical and mechanical characteristics within functional limits to achieve a screen with reduced visibility.

Inside and Outside Viewers

With reference to FIG. **5**, a cross-sectional view of a dwelling **500** is shown to illustrate how inside and outside observers view screens. Dwelling **500** separates the outside **502** from the inside **504**. An inside viewer **506** is illustrated inside **504** of the dwelling **500** while an outside viewer **508** is illustrated outside **502**. Window **510** is located in a wall of dwelling **500** and also separates the inside **504** from the outside **502**. Screen **512** covers the window **510** on the outside **502** side of window **510**.

The inside viewer **506** in FIG. **5** is separated from window **510** by the width of sink **518**, which represents a typical close range interior viewing distance, frequently about 2 feet. The closer the viewer **506** stands to the screen **512**, the more obvious the screen **512** will appear. For example, at 12 inches, which is a relatively close range interior viewing distance, the normal visual acuity of the human eye is about 0.0035 inch (about 0.0888 mm). Elements having a diameter of less than about 0.0035 inch will likely not be perceived by a viewer of normal eyesight at a distance of 12 inches (30.48 cm). Therefore, the perceived visibility is affected by the diameter of the screen elements and the distance between the viewer **506** and the screen **512**. At about 24 inches, the normal visual acuity is about 0.007 inch. For this reason, elements having a diameter of about 0.007 inch will not be resolvable to a viewer at about 24 inches from the screening.

Inside a building or dwelling, interior lighting fixtures such as light **514** provide the primary interior light source that would reflect from the screen. Outside of the dwelling, the sun **516** provides a much stronger light source that will reflect off the screen **512**. Accordingly, the reflectance of the screen will generally be of greater importance to the visibility of the screen to the outside viewer **508** than to the inside viewer **506**, because much more light is incident on the screen from the exterior **502** than from the interior **504**. However, the shape of the elements, which are normally round, may cause sunlight to be reflected into the interior of the building, impacting the visibility of the screen to an inside viewer.

The transmittance of the screen affects visibility of the screen for both the inside viewer **506** and the outside viewer **508**. The inside viewer **506** views the exterior scene by the sunlight that is reflected off the outside objects and then transmitted through the screening **512**. The less light transmitted through the screening **512**, the more the inside viewer's perception of the exterior view is negatively affected by the screening. As discussed above in relation to FIG. **4**, when looking through the screening, the exterior viewer sees light reflecting from or emanating from the objects on the interior side of the screening. As the transmittance of the screening decreases, the presence of the screening becomes more apparent.

The perspective of inside and outside viewers has been discussed so far with respect to a screen that is on the exterior side of a window. This is the configuration used in most double hung windows, sliding windows, and sliding doors. However, many window units have screens on the interior side of the window, such as casement windows or awning windows. Where the screen is inside of the glass, the reflectance and transmittance of the insect screening will still impact the visibility of the screen. Generally, screens on the outside of the glass are the most obvious type to the outside viewer, so this is the harder configuration to address for outside viewing. As discussed above, the size of the individual screen elements has an important impact on the visibility of a screen to an inside observer. If a screening possesses reflectance and transmittance qualities that are acceptable for outside viewing, and a sufficiently small element diameter, the screening will also be less visible to the inside observer than conventional insect screens, whether the screen is on the inside or outside of the glass.

Specular Versus Diffuse Reflectance

FIG. **9** illustrates two types of reflection that occur from surfaces: specular reflection and diffuse reflection. In specular reflection, light has an angle of reflection measured from the normal to the surface that is equal to the angle of incidence of the beam measured from the normal, where the reflected beam is on the opposite side of the normal to the surface from the incident beam. In diffuse reflection, an incident beam of light is reflected at a range of angles that differ significantly from the angle of incidence of the incident parallel beam of light.

In FIG. **9**, light rays are shown interacting with a surface **902**. Light ray **904** is incident on the surface **902** at an angle of incidence α_i. A portion of the light ray **904** is specularly reflected as light ray **906**, where the angle of reflection α_r is equal to the angle of incidence α_i. However, light rays **908**, **910**, and **912** are examples of diffusely reflected light rays that are reflected at a range of different reflection angles.

For reducing the visibility of screening, diffuse reflection is preferred over specular reflection because diffuse reflection disperses the power of the incident light over multiple angles. In specular reflection, the light beam is generally redirected to the reflection angle while maintaining much of its power. Providing a dull or roughened surface increases diffuse reflection from a screen mesh.

Reflectance & Transmittance Testing Procedure

Measurements for reflectance and transmittance may be made with an integrating sphere spectrophotometer. For the purposes of the data presented herein, a Macbeth Color-Eye 7000 spectrophotometer, manufactured by GretagMacbeth of Germany, was used to obtain transmittance and reflectance measurements for wavelengths of 360 to 750 nm.

The spectrophotometer shown in FIG. **15** contains an integrating sphere **1502** useful when measuring samples in reflection or transmission. Integrating sphere **1502** contains front port **1510** and exit port **1508**. The front port **1510** measures about 25.4 mm in diameter.

A xenon flash lamp **1504** is located at the base of the integrating sphere. Detector **1506** measures the amount of light emitted from integrating sphere **1502**. Detector **1506** contains viewing lens **1512** for viewing the light. Viewing lens **1512** contains a large area view.

For reflectance measurement, the spectrophotometer is set to a measurement mode of: CRILL, wherein the letters correspond to the following settings for the machine: C—Reflection, specular included; R—Reflection; I—Included Specular, I—Included UV; L—Large Lens; L—Large Aperture. When measuring reflectance, the sample is held flat against the front port **1510**. Next, a light trap is placed behind the sample to prevent stray light from entering integrating sphere **1502**. The light source **1504** emits light into the integrating sphere **1502**. Some of the light is reflected off the sample and exits the integrating sphere **1502** through the exit port **1508**. Once the light exits the exit port **1508**, it enters the detector **1506** through viewing lens **1512**. The spectrophotometer produces a number that is a ratio indicating the light reflected by the sample relative to the light reflected by a perfectly reflective surface.

For a transmittance measurement, the spectrophotometer is set to a measurement mode of: BTIILL, wherein the letters correspond to the following settings for the machine: B—Barium; T—Transmittance; I—Included Specular, I—Included UV; L—Large Lens; L—Large Aperture. The front port **1510** of the spectrophotometer is blocked with an object coated with barium oxide, identical to the interior surface of the sphere **1502**. When measuring the transmittance of a sample, it is necessary to hold the sample flat against the exit port **1508** of the integrating sphere **1502**. The light source **1504** emits light into the integrating sphere **1502**. Some of the light exits the integrating sphere **1502** through exit port **1508**. Once the light that is transmitted through the sample enters the detector **1506** through viewing lens **1512**, the spectrophotometer produces a number that is a ratio indicating the light transmitted by the sample relative to the light transmitted where there is no sample.

Data collected for reflectance and transmittance for a number of screen samples will be described below with respect to FIGS. **6** and **7**.

Data for Reflectance and Transmittance

Table 1 contains average values of test data for optical qualities of insect screening embodiments.

TABLE 1

Optical Data for Examples

Sample	Description	Transmittance	Reflectance
1	Black Zn Cr	0.828	0.006
2	Flat Paint	0.804	0.012
3	Glossy Paint	0.821	0.014
4	Black Ink	0.874	0.013
5	PVD Cr(x)C(y)	0.887	0.019
6	Stainless Steel Base	0.897	0.044

Examples of the present invention will now be described. Six different samples were prepared and tested for optical qualities related to the present invention.

Each of Samples 1–6 was formed by starting with a base screening of stainless steel elements having a diameter of 0.0012 inch. The elements are made of type **304** stainless steel wire. The base screening has 50 elements per inch in both horizontal and vertical directions. It is a woven material and has openings with a dimension of 0.0188 inch by 0.0188 inch. The open area of this base material is about 88%, measured experimentally using a technique that will be described further herein. This material is commercially available from TWP, Inc. of Berkley, Calif. Sample 6 is the base screening without any coating. FIG. **10** is a photograph of Sample 6 taken through a microscope.

To form Sample 1, the base screening was coated by electroplating it with zinc and then a conversion coating of silver chromate was applied. The zinc reacts with the silver chromate to form a black film on the surface of the screen elements. A photograph of Sample 1 taken through a microscope is shown in FIG. **11**. The black zinc coating bonds the horizontal and vertical screen elements together at their intersections. The coating increases the thickness of the screen element and therefore reduces the transmittance of the resulting screening by about 0.07 compared to the uncoated screening of Sample 6. The black finish decreases reflectance of incident light dramatically compared to the uncoated Sample 6.

To form Samples 2 and 3, the base screening was coated with about two to three coats of flat black paint and glossy black paint, respectively. As the paint was being applied manually, the painter visually inspected the surface and attempted to apply a uniform coating of paint. Depending on the speed of the spray apparatus passing over the various portions of the surface, two or three coats were applied to different areas of Samples 2 and 3, based on the painter's visual observations, to achieve a fairly even application of paint. Photographs of Samples 2 and 3 taken through a microscope are shown in FIGS. **12** and **13**, respectively. The paint coating joins the horizontal and vertical screen elements together at their intersections and provides a black finish. The coating increases the thickness of the screen element and therefore reduces the transmittance of the resulting screening compared to the uncoated screening of Sample 6. The black color of both Samples 2 and 3 decreases reflectance of incident light compared to the uncoated Sample 6, with the flat black paint of Sample 2 having a lower reflectance than the glossy paint.

Sample 4 was coated with black ink. The application of ink to the screening does not significantly bond or join the horizontal and vertical screen elements together at their intersections. The coating of ink increases the thickness of the screen element a small amount and therefore reduces the transmittance of the resulting screening compared to the uncoated screening of Sample 6. The black finish decreases the reflectance of incident light compared to the uncoated Sample 6.

Sample 5 was coated with chromium carbide by physical vapor deposition (PVD). A photograph taken through a microscope of Sample 5 is shown in FIG. **14**. The chromium carbide coating does not bond the horizontal and vertical screen elements together at their intersections, but does provide a black finish. The coating increases the thickness of the screen element very slightly and therefore reduces the transmittance of the resulting screening compared to the uncoated screening of Sample 6. The black finish decreases reflectance of incident light compared to the uncoated Sample 6.

Several commercially available insect screenings were tested for their optical qualities as a basis for comparison to the samples of the invention. The following table contains average values of actual test data from each material.

TABLE 2

Optical Data for Comparative Examples

Sample	Description (material, color, manufacturer, trade name if any)	Transmittance	Reflectance
A	Al, Gray, Andersen Windows	0.658	0.025
B	FG, Black, Andersen Windows	0.576	0.029
C	FG, Black, Phifer	0.625	0.025
D	Al, metallic, Phifer, Brite-Kote ™	0.779	0.095
E	Al, Charcoal, Phifer	0.741	0.019
F	Polyester, Black, Phifer, Pet Screen ®	0.363	0.024
G	FG, Gray, Phifer	0.652	0.060

Samples A, D and E are made of aluminum elements. Samples B, C, and G are made of vinyl-coated fiberglass elements. Sample F is made of a polyester material.

FIG. **6** shows a comparison of reflectance values for both commercially available screening Samples A–G and screenings of the present invention Samples 1–6. Lower values for reflectance correspond to screening that appears more invisible because less light is reflected in the direction of the viewer. Samples 1–4 have the lowest values for reflectance. The least reflective commercially available Sample E has an average reflectance value of 0.019, which is equivalent to the average value of the second-most reflective Sample 5.

FIG. **7** shows a comparison of transmittance values for the screen materials set forth in the tables above. Higher values for transmittance correspond to screens with preferred optical qualities. Screening Samples 1–6 have higher transmittance values than the commercially available Samples A–G.

FIG. **8** is a graph of transmittance versus reflectance for the screen materials set forth in the tables above. Samples 1–5 all have a transmittance of at least about 0.80 and a reflectance of no more than about 0.020. None of the comparative samples have a transmittance greater than 0.78. None of the comparative samples have both a transmittance of greater than 0.75 or 0.80 and a reflectance of less than 0.020, 0.025, 0.030 or 0.040, while samples 1–5 have those qualities.

Percent Open Area

The percent open area also relates to the invisibility of an insect screen. Assuming a square mesh, the percent open area (POA) can be computed as follows:

$$POA=((W)(D+W))^2*100$$

where:

D=element diameter, and
W=opening width.

Many commercially available screenings have a rectangular mesh. The POA for a rectangular mesh can be computed as follows:

$$POA=(1-N*D)(1-n*d)*100$$

where:

N=number of elements per inch in a first direction,
D=element diameter of the elements extending in the first direction,
n=number of elements per inch in a second direction, and
d=element diameter of the elements extending in the second direction

Generally, screens appear less visible if they contain a larger percentage of open area. For example, Sample 6 has about 88% open area, corresponding to 50 elements per inch in either direction, screen elements of woven 0.0012-inch (0.03-mm) type **304** stainless steel wire, and openings sized 0.0188 inch (0.5 mm)×0.0188 inch (0.5 mm).

In contrast, standard insect screening has about 70% open area and often have opening sizes of 0.05 inch by 0.04 inch. Standard gnat-rated insect screens often have a percent open area of about 60% and opening sizes of about 0.037 inch by 0.037 inch with elements of about 0.013 diameter.

Decreasing the wire diameter can increase the percent open area. It is desirable to select a wire diameter that allows for the largest percent open area while maintaining suitable strength. Screening is commercially available made of unwelded **5056** aluminum wire of 0.011-inch (0.279 mm) diameter. The term unwelded indicates that the horizontal and vertical elements are not bonded or welded together at their intersections. Importantly, type **304** stainless steel wire has almost three times the tensile strength of **5056** aluminum wire. Accordingly it is possible to use a smaller wire diameter of 0.0066 inch (0.1676 mm) of type **304** stainless steel to achieve tensile strength similar to the **506** aluminum screening.

Additional materials may be selected within the scope of the present invention to increase the percent open area by decreasing the diameter of the screen elements. These materials include, but are not limited to: steel, aluminum and its alloys, ultra high molecular weight (UHMW) polyethylene, polyesters, modified nylons, and aramids. It is also possible to use an array of man-made fibers for generalized use in the industrial arts. An example of this material is sold under the trademark KEVLAR®.

Generally, the percent open area corresponds roughly to the percentage of transmittance through a particular screening. However, accepted techniques for calculating percent open area like those expressed above do not account for the elements crossing each other in the screening, and therefore over-estimate the percent open area by a few percent. The amount of error inherent in these calculations depends on the thickness of the wire.

Strength of Screen Elements

FIG. **18** illustrates the single element ultimate tensile strength for elements of Sample 6 and comparative Samples A, B, D, E and F. Samples 1–5 consist of the same material as Sample 6 but with a coating added. Therefore Samples 1–5 have ultimate tensile strengths that are about the same as for Sample 6. The electroplated zinc coating applied to Sample 1 may in fact increase the ultimate tensile strength of those elements.

As discussed above, the diameter of the elements in Sample 6 is much smaller than commercially available insect screen elements. Therefore, inventive elements must have a higher tensile strength than elements used in prior screening materials to achieve similar strength specifications as prior screening materials. In FIG. **18**, ultimate tensile strength is charted in Ksi or 1000x psi. The tensile strength for the elements of Sample 6 is about 162 Ksi, which is over

three times stronger than Sample D, which is the strongest element in the commercially available Samples A, B, D, E and F. A minimum desirable tensile strength for the screen elements is about 5500 psi or more, or about 6000 psi or more. Preferably, at least about a tenth of pound of force is required to cause a single screen element to break. About 0.16 pound force is required to break a 0.0012-inch stainless steel element of Sample 6.

Snag Resistance

Snag resistance is a measure of how a screen reacts to forces that could cause a break, pull, or tear in the screen elements, such as clawing of the screening by a cat. Snag resistance is important because birds, household animals, and projectiles come into contact with screens.

FIGS. **16** and **17** show a test fixture **1700** used to measure snag resistance. Test fixture **1700** includes a screen guide **1702** made from two 0.5x6-inch pieces of fiberglass laminate material **1710** and **1712**. The pieces **1710** and **1712** are approximately 0.060 inches thick and are used to guide the screen cloth **1704** during the test by placing the screen cloth **1704** between pieces **1710** and **1712** of screen guide **1702**. The pieces **1710** and **1712** contain an upper clearance hole to attach the screen guide **1702** to an instrument that measures the maximum load. Pieces **1710** and **1712** also contain a lower clearance hole to support a snagging mandrill **1706**.

When preparing a sample of screening **1704** for a test, a 2-inchx6-inch sample strip of screen **1704** is cut out so that the warp and weft directions lie with and perpendicular to the test direction. The warp direction is along the length of a woven material while the weft direction is across the length of the woven material. The screen guide **1702** is hung from a load cell gooseneck and a snagging mandrill **1706** is carefully passed through the screen **1704**. The test is started and the snag mandrill **1706** is moved through the screen **1704** at the rate of 0.5 inch/minute and continued until 0.5 inch is traveled. At this point, the test is terminated and the sample is removed. Care must be taken not to damage the sample when removing it from the test fixture. Several measurements may be recorded, including the maximum load obtained and the load at a specific extension divided by the extension (lb-force/in).

Samples were also visually inspected to determine the failure mode. Three failure modes are generally possible with insect screens. The first failure mode is element breakage because the joints hold and the sections of element between the joints break. The second failure mode is joint breakage. This occurs when the elements hold and the joints break. The third failure mode occurs when the elements break and the joints slip. This third failure mode is a combination of element breakage and joint breakage. Generally, element breakage is the preferred failure mode because it disturbs less surface area on the screen.

FIG. **19** illustrates a screen with unbonded elements corresponding to Sample 6 after undergoing the snag resistance test described above. The screen elements appear to have slid together due to the force of the snagging mandrill **1706**. FIG. **19** is generally an example of the joint breakage failure mode. As no coating forms a bond at the intersections of the elements in Sample 6, any joint strength is due to frictional forces between the elements in the weave.

Conversely, FIG. **20** shows a screen with elements coated and joined at their intersections by paint after undergoing the snag resistance test. Unlike the unbonded elements shown in FIG. **19**, the painted elements appear to have broken at several locations rather than merely sliding together. FIG. **20** is an example of the element breakage and joint breakage failure mode discussed above. The failure mode shown in FIG. **20** is preferred over the failure mode shown in FIG. **19** because less surface area is disturbed on the screen, creating a more desirable appearance, and a less visible screening, after a snag. The element breakage mode is preferred over the element breakage and joint breakage failure mode because even less surface area is disturbed on the screening.

To achieve an element breakage mode, the joint strength needs to be sufficient to cause the elements to give way before the joints when a snagging force is applied to the screening. On the other hand, it may be desirable in some situations to select element and joint strength so that joint breakage occurs before element breakage, resulting in a more resilient screen. When a force is applied to this type of screening, the element stays intact while the bonds break or slip. The force on the element is then distributed to the other adjacent bonds.

FIGS. **21–25** illustrate the screen snag resistance of Samples 1–3 and 5–6 in terms of pounds of force versus displacement of the snag mandrill **1706**. Samples 5 and 6, shown on FIGS. **21** and **22**, respectively, show a relatively smooth curve compared to Samples 1–3, shown on FIGS. **23–25**, respectively. A smooth curve indicates that the joints between elements are very weak or not bonded. Sample 4 would likely have results similar to Sample 6 in FIG. **22**, as the ink coating does not form significant bonds. The joints on Samples 1–3 are much stronger than the joints on Samples 5 and 6. Accordingly, the graph lines on FIGS. **23–25** for Samples 1–3 have several jagged edges. Each sharp drop in the graph corresponds to an element break or a bond break. Sample 2 was able to withstand the largest amount of force of all the samples before an element or bond break.

Size and Spacing of Exemplary Screen Elements

In FIG. **2**, a width or diameter W of the screen elements **70** is illustrated. The width W may be less than about 0.007 inch or 0.0035 inch to fall beneath the visual acuity of a normal viewer at either 24 inches or 12 inches, respectively. The smaller the screen element that meets strength requirements, the less visible will be the insect screening. In another embodiment, W is about 0.001 inch (about 0.0254 mm) to about 0.0015 inch (about 0.0381 mm), or about 0.0012 inch. Stainless steel wire, for example, can be provided in this size range and be sufficiently strong for use in insect screening. Each screen element **70** has a length to span the distance between opposed frame members **50**, **60** (FIG. 1).

The plurality of screen elements **70** includes a plurality of horizontal screen elements **80** and a plurality of vertical screen elements **90**. The horizontal screen elements **80** are spaced apart from each other a distance D_V and the vertical screen elements **90** are spaced apart from each other a distance D_H. The spacing depends on the types of insects the user wishes to exclude. Opening sizes are chosen to exclude the types of insects that the screening is designed to keep out. Preferably, the largest values for D_H and D_V are selected that still exclude the targeted insects, so that transmittance is maximized and reflection is minimized.

A screen mesh that excludes most insects is typically constructed with a D_V and D_H of about 0.040 inch (about 1.016 mm) or 0.050 inch (about 1.27 mm). For a screen mesh for excluding smaller insects, like gnats or no-see-ums, a smaller mesh opening is necessary, such as a square opening with a D_H and D_V of about 0.037 or 0.04 inch (about 1 mm).

In embodiments of the present invention, D_H and D_V may be less than about 0.060 inch (about 1.523 mm), less than about 0.050 inch (about 1.27 mm), less than about 0.040 inch (about 1.016 mm), or less than about 0.030 inch (about 0.7619 mm). D_V and D_H may be equal to form a square opening, or they may differ so that the mesh opening is rectangular. For example, D_V may be about 0.050 inch (about 1.27 mm) while D_H is about 0.040 inch (about 1.016 mm). All other permutations of the above mentioned dimensions for D_H and D_V are also contemplated. Typically, the vertical

and horizontal screen elements are positioned to be perpendicular to each other and aligned with the respective frame members.

TABLE 3

Dimension Data for Examples

Screen Sample	Experimentally Measured Percent Black Area	Percent Open Area	Avg. Element Diameter (mm) +/- 0.002	Avg. Element Diameter (mils) +/- 0.08	Avg. Coating Thickness (mm) +/- 0.001	Avg. Coating Thickness (mils) +/- 0.1
1 Black Zn	17.0%	83%	0.039	1.5	0.004	0.15
2 Flat Paint	19.6%	80.4%	0.045	1.8	0.007	0.28
3 Glossy Paint	18.4%	81.6%	0.042	1.7	0.006	0.24
6 Stainless Steel Base	14.1%	85.9%	0.033	1.3	—	—

Table 3 below lists experimentally measured screen element dimensions for Samples 1–3 and 6. The percent black area is the percentage of the screening that is occupied by the screen elements. The percent open area and the black area add 100 for a specific screening.

The experimental measurements of Samples 1–3 and 6 in Table 3 were measured by backlighting a sample of each screening and taking a digital photograph. The percent of black area on the photo image was then measured using image analysis software. Knowing the number of elements that were present in each image and the dimensions of the sample, the average coated element thickness was calculated for column 3. For each of Samples 1–6, the underlying uncoated element has a diameter of 0.0012 inch, so this amount was subtracted from the coated element diameter of column 3 to arrive at the average coating thickness of columns 4 and 5.

The PVD CrC coating of Sample 5 and the ink coating of Sample 4 are too thin to be reliably measured by this experimental technique. Based on the deposition technique, the coating of Sample 5 is estimated to be about 0.02 mils (0.5 μm). Because this coating and the ink coating are extremely thin, the percent black area for Samples 4 and 5 are roughly equivalent to the uncoated Sample 6.

The plurality of horizontal and vertical screen elements **80**, **90** can be constructed and arranged to form a mesh where a horizontal screen element intersects a vertical screen element perpendicularly. The intersecting horizontal and vertical screen elements **80**, **90** may be woven together. Optionally, the intersecting horizontal and vertical screen elements **80**, **90** are bonded together at their intersections, as described in more detail below with respect to coating alternatives.

Materials for the Screen Mesh

In order to provide a material for the screening **30** that will withstand the handling that is associated with screen use, several factors are important, such as the screen element diameter and the ultimate tensile strength of the material. In addition, other factors are considered in selecting a material, such as the coefficient of thermal expansion, the brittleness, and the plasticity of a material. The coefficient of thermal expansion is significant because expansion or contraction of the screen elements due to temperature changes may alter the normal alignment of the horizontal and vertical screen elements, thereby leading to visible distortion of the screening.

In one embodiment, materials from the categories of glass fibers, metals or polymers meet the requirements for screen element strength at the desired diameters, such as steel, stainless steel, aluminum, aluminum alloy, polyethylene, ultra high molecular weight polyethylene, polyester, modified nylon, polyamide, polyaramid, and aramid. One material that is particularly suited for the screen elements is stainless steel. The high tensile strength of about 162 Ksi and low coefficient of thermal expansion of about $11\times10^{-6}K^{-1}$ for stainless steel are desirable.

Coating or Finish Alternatives

The surface **100** of the screen elements **70** is a dark, non-reflective, and preferably dull or matte finish. A dark non-reflective, dull or matte finish is defined herein to mean a finish that absorbs a sufficient amount of light such that the screen mesh **30** appears less obtrusive than a screen mesh **30** without such finish. The dark non-reflective or matte finish may be any color that absorbs a substantial amount of light, such as, for example, a black color. The dark non-reflective or matte finish can be applied to the screen element surface **100** by any means available such as, for example, physical vapor deposition, electroplating, anodizing, liquid coating, ion deposition, plasma deposition, vapor deposition, and the like. Liquid coating may be, for example, paint, ink, and the like.

For example, a PVD chromium carbide coating or black zinc coating may be applied to the screen elements in one embodiment. The black zinc coating is prefered to the CrC coating because it is rougher, more matte, and less shiny. Alternatively, glossy or flat black paint or black ink may be applied to the screen elements. The flat paint coating is preferred to the glossy paint coating because it is less reflective. Other carbides can also be used to provide a dark finish, such as titanium aluminum carbide or cobalt carbide.

The use of a coating on the screen elements may provide the additional advantage of forming a bond at the intersections of the screen elements. A coating of paint provides some degree of adhesion of the elements at the intersections. Some coatings such as black zinc create bonds at the intersections of the elements. The coating thickness and overall element diameter for Samples 1–3 and 5–6 are listed in Table 3 above.

The improved screening materials of the invention typically comprise a mesh of elements in a screening material. The elements comprise long fibers having a thin coating disposed uniformly around the fiber. The coating comprises the layer that is about 0.10 to 0.30 mils (about 0.00253 to 0.0076 mm), preferably about 0.15 mils (about 0.0038 mm). Virtually any material can be used in the coating of the invention that is stable to the influence of outdoor light, weather and the mechanical shocks obtained through coating manufacture, screen manufacture, window assembly,

storage, distribution and installation. Such coatings typically have preferred formation technologies. The coatings of this invention, however, can be made using aqueous or solvent based electroplating, chemical vapor deposition techniques and the application of aqueous or solvent based coating compositions having the right proportions of materials that form the thin durable coatings of the invention. Both organic and inorganic coatings can be used. Examples of organic coatings include finely divided carbon, pigmented polymeric materials derived from aqueous or solvent based paints or coating compositions, chemical vapor deposited organic coatings and similar materials. Inorganic coating compositions can include metallic coatings comprising metals such as aluminum, vanadium, chromium, manganese, iron, nickel, copper, zinc, silver, tin, antimony, titanium, platinum, gold, lead and others. Such metallic coatings can be two or more layers covering the element and can include metal oxide materials, metal carbide materials, metal sulfide materials and other similar metal compounds that can form stable, hard coating layers.

Chemical vapor deposition techniques occur by placing the screening or element substrate in an evacuated chamber or at atmosphere and exposing the substrate to a source of chemical vapor that is typically generated by heating an organic or inorganic substance causing a substantial quantity of chemical vapor to fill the treatment chamber. Since the element or screening provides a low energy location for the chemical vapor, the chemical vapor tends to coat any uncoated surface due to the interaction between the element and the coating material formed within the chamber.

In electroplating techniques, the element or screening is typically placed in an aqueous or solvent based plating bath along with an anode structure and a current is placed through the bath so that the screen acts as the cathode. Typically, coating materials are reduced at the cathode and that electrochemical reduction reaction causes the formation of coatings on the substrate material.

Applications for the Insect Screen

The screening **30** can be used with or without a frame **20** in certain applications, such as in a screen porch or pool enclosure. The insect screen **10** can be used in conjunction with a fenestration unit **110**, such as a window or door. The insect screen **10** may be used in any arrangement of components constructed and arranged to interact with an opening in a surface such as, for example, a building wall, roof, or a vehicle wall such as a recreational vehicle wall, and the like. The surface may be an interior or exterior surface. The fenestration unit **110** may be a window (i.e. an opening in a wall or building for admission of light and air that may be closed by casements or sashes containing transparent, translucent or opaque material and may be capable of being opened or closed), such as, for example, a picture window, a bay window, a double-hung window, a skylight, casement window, awning window, gliding window and the like. The fenestration unit **110** may be a doorway or door (i.e. a swinging or sliding barrier by which an entry may be closed and opened), such as, for example, an entry door, a patio door, a French door, a side door, a back door, a storm door, a garage door, a sliding door, and the like.

The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

We claim:

1. A reduced visibility insect screening in a fenestration unit that permits ventilation therethrough having a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

2. The insect screening of claim **1** wherein the transmittance of the screening is at least 0.80.

3. The insect screening of claim **2** wherein the reflectance of the screen is 0.02 or less.

4. The insect screening of claim **1** wherein the reflectance of the screening is 0.03 or less.

5. The insect screening of claim **1** wherein the reflectance of the screen is 0.02 or less.

6. The insect screening of claim **1** having an open area of at least 75%.

7. The insect screening of claim **1** having an open area of at least 80%.

8. The insect screening of claim **1** comprising a plurality of screen elements, each screen element having a diameter less than 0.005 inch.

9. The insect screening of claim **8** wherein the screen elements have a tensile strength greater than 5500 psi.

10. The insect screening of claim **9** wherein the screen elements define mesh openings having a largest dimension not greater than 0.060 inch.

11. The insect screening of claim **1** comprising a plurality of screen elements, each screen element having a tensile strength greater than 5500 psi.

12. The insect screening of claim **1** wherein the screen elements define mesh openings having a largest dimension not greater than 0.060 inch.

13. The insect screening of claim **1** comprising a metal selected from the group consisting of steel, stainless steel, aluminum and aluminum alloy.

14. The insect screening of claim **1** comprising a polymer selected from the group consisting of polyethylene, polyester and nylon.

15. The insect screening of claim **1** comprising an ultra high molecular weight polyethylene.

16. The insect screening of claim **1** comprising an amide selected from the group consisting of polyamide, polyaramid and aramid.

17. The insect screening of claim **1** comprising a dark coating.

18. The insect screening of claim **1** comprising a coating selected from the group consisting of physical vapor deposited chromium carbide and electroplated black zinc.

19. The insect screening of claim **1** comprising a plurality of screen elements, where each screen element includes:

stainless steel; and

a coating having a thickness of about 0.10 to 0.30 mils.

20. The insect screening of claim **1** comprising a plurality of screen elements, where each screen element includes:

stainless steel; and

a coating including electroplated black zinc.

21. A reduced visibility insect screen comprising:

a frame defining a frame opening; and

the screening of claim **1** attached to the frame around the frame opening.

22. An insect screening material in a fenestration unit that permits ventilation therethrough having reduced visibility, comprising a plurality of screen elements having a diameter of 0.007 inch or less, the screen elements having a tensile strength greater than 5500 psi, wherein the screening has a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

23. A reduced visibility insect screen comprising:

a frame defining a frame opening; and

the screening material of claim **22** attached to the frame around the frame opening.

24. The screening of claim **22** wherein the screening material defines mesh openings having a largest dimension not greater than 0.060 inch.

25. The screening material of claim **22** wherein the transmittance of the screening is at least 0.80.

26. The screening material of claim **25** wherein the reflectance is 0.02 or less.

27. The screening material of claim 22 wherein the reflectance of the screening is 0.03 or less.

28. The screening material of claim 22 wherein the reflectance is 0.02 or less.

29. The screening material of claim 22 wherein the screening has an open area of at least 75%.

30. The screening material of claim 22 wherein the screen elements comprise a metal selected from the group consisting of steel, stainless steel, aluminum and aluminum alloy.

31. The screening material of claim 22 wherein the screen elements comprise a polymer selected from the group consisting of polyethylene, polyester and modified nylon.

32. The screening material of claim 22 wherein the screen elements comprise an ultra high molecular weight polyethylene.

33. The screening material of claim 22 wherein the screen elements comprise an amide selected from the group consisting of polyamide, polyaramid and aramid.

34. The screening material of claim 22 wherein the screen elements comprise a dark coating.

35. The screening material of claim 22 wherein the screen elements comprise a coating selected from the group consisting of physical vapor deposited chromium carbide and electroplated black zinc.

36. The screening material of claim 22 wherein each screen element comprises:

stainless steel; and

a coating having a thickness of about 0.10 to 0.20 mils.

37. The screening material of claim 22 wherein each screen element comprises:

stainless steel; and

a coating including electroplated black zinc.

38. A screening in a fenestration unit that permits ventilation therethrough comprising:

a plurality of screen elements having a diameter of 0.007 inch or less; and

a coating on the screen elements having a dark finish;

wherein the screening has a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

39. The screening of claim 38 wherein the screen elements have a tensile strength greater than 5500 psi.

40. The screening of claim 38 wherein the coating has a thickness of 0.10 to 0.30 mils.

41. An insect screen having reduced visibility, comprising:

a frame defining a frame opening; and

the screening of claim 38 attached to the frame around the frame opening.

42. The screening of claim 38 wherein the screening defines mesh openings having a largest dimension not greater than 0.060 inch.

43. The screening of claim 38 wherein the transmittance of the screening is at least 0.80.

44. The screening of claim 43 wherein the reflectance of the screening is 0.02 or less.

45. The screening of claim 38 wherein the reflectance of the screening is 0.03 or less.

46. The screening of claim 38 wherein the reflectance of the screening is 0.02 or less.

47. The screening of claim 38 wherein the screening has an open area of at least 75%.

48. The screening of claim 38 wherein the screen elements comprise a metal selected from the group consisting of steel, stainless steel, aluminum and aluminum alloy.

49. The screening of claim 38 wherein the screen elements comprise a polymer selected from the group consisting of polyethylene, polyester and modified nylon.

50. The screening of claim 38 wherein the screen elements comprise an ultra high molecular weight polyethylene.

51. The screening of claim 38 wherein the screen elements comprise an amide selected from the group consisting of polyamide, polyaramid and aramid.

52. The screening of claim 38 wherein the coating is selected from the group consisting of physical vapor deposited chromium carbide and electroplated black zinc.

53. The screening of claim 38 wherein each screen element includes stainless steel and the coating has a thickness of about 0.10 to 0.20 mils.

54. The screening of claim 38 wherein each screen element includes stainless steel and the coating includes electroplated black zinc.

55. The insect screening of claim 1 comprising a plurality of screen elements, each screen element having a diameter less than 0.007 inch.

56. The insect screening of claim 22 comprising a plurality of screen elements, each screen element having a diameter less than 0.005 inch.

57. The insect screening of claim 38 comprising a plurality of screen elements, each screen element having a diameter less than 0.005 inch.

58. The insect screening of claim 1 wherein the fenestration unit is a window.

59. The insect screening of claim 22 wherein the fenestration unit is a window.

60. The insect screening of claim 38 wherein the fenestration unit is a window.

61. The insect screening of claim 1 wherein the fenestration unit is a door.

62. The insect screening of claim 22 wherein the fenestration unit is a door.

63. The insect screening of claim 38 wherein the fenestration unit is a door.

64. The insect screening of claim 1 comprising a plurality of intersecting screen elements, wherein the screen elements are bonded at their intersections.

65. The insect screening of claim 22 comprising a plurality of intersecting screen elements, wherein the screen elements are bonded at their intersections.

66. The insect screening of claim 38 comprising a plurality of intersecting screen elements, wherein the screen elements are bonded at their intersections.

67. A method of screening insects comprising:

providing a reduced visibility insect screening having a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less; and,

mounting the screening in an insect screen frame.

68. The method of claim 67 wherein the insect screen frame is disposed in an opening of a building structure, in a window, in a window frame, in a door, or in a door frame.

69. The method of claim 67 wherein a window or a door is disposed in the opening.

70. A method of screening insects comprising:

providing a reduced visibility insect screening having a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less; and,

spanning the screening across an opening of a building structure.

71. The method of claim 70 wherein the building structure forms a frame for an insect screen.

72. The method of claim 71 wherein the insect screen frame is disposed in a window, in a window frame, in a door, or in a door frame.

73. The method of claim 70 wherein a window or door is disposed in the opening.

74. A reduced visibility insect screening spanning an opening of a building structure that permits ventilation therethrough having a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

75. A reduced visibility insect screening in a frame removably attached to a fenestration unit that permits ven-

tilation therethrough having a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

76. An insect screening material in a frame removably attached to a fenestration unit that permits ventilation therethrough and having reduced visibility, comprising a plurality of screen elements having a diameter of 0.007 inch or less, the screen elements having a tensile strength greater than 5500 psi, wherein the screening has a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

77. A screening in a frame removably attached to a fenestration unit that permits ventilation therethrough comprising:

a plurality of screen elements having a diameter of 0.007 inch or less; and

a coating on the screen elements having a dark finish;

wherein the screening has a transmittance of light of at least 0.75 and a reflectance of light of 0.04 or less.

* * * * *

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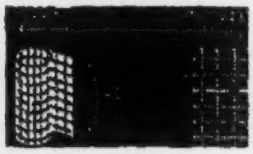

Technical Information [High Transparency Wire Mesh]

These "optical grade" precision stainless steel meshes are used for manufacturing shielded CRT screens and transparent radio frequency (RF) shielded windows and in TEMPEST HERF EMI EMP mesh applications

These meshes are produced using highly sophisticated wire drawing and weaving technologies. Stainless steel T304 rod is drawn to an extremely smooth close tolerance wire many times finer a single strand of human hair. A computer-controlled loom weaves this into the world's most del metal fabric.

The result is a highly transparent, uniform mesh. It is used in shielded windows and cathode ray tubes (CRT's). Our mesh qualifies as "optical grade". It requires great care in handling. This mat is woven to ISO 9044.

Closeouts, overstocks, and discount high transparency wire meshes may be available.

Sample Policy: There is a charge of $12.50 for the first sample and additional samples are $5.(each. This price includes shipping via U.S. Priority Mail or Global Priority Mail.
High Transparency wire mesh sample size is 3 inch x 3 inch
Credit cards only please.

≙ Back to top

High Transparency Wire Mesh Data

Mesh Per Inch	Wire Dia. Inches	Opening Inches	Opening Microns	Open Area %	Weave Type	Weight LBS Per 100 SFT	Roll Width Inches	Part #	Pr
50	0.0012	0.0188	477	88	PSW	0.39	48	050X050S0012W48T	[
80	0.0012	0.0113	287	82	PSW	0.61	48	080X080S0012W48T	[
100	0.0011	0.0089	226	79	PSW	0.76	48	100X100S0011W48T	[

≙ Back to top

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